The Great Toy Design Challenge

Home Connection

Dear Family,
During the last few days, your child worked on a team to design a new toy for the fictional Sir Isaac's Toy Company. The students acted just like engineers! They

- identified and learned about a problem
- planned ways to solve the problem
- made and tested a prototype
- revised their design to make it better

In this challenge, students learned about properties of materials, how some fluids act differently under stress, and equivalent fractions. They also practiced skills such as developing and using special models called prototypes, making claims based on evidence, and communicating technical information.

Let your child tell you about what the team did in this engineering effort and how the team developed their own toy that was better than the existing products in the market. Use prompts such as these to start your child talking.

- What was the problem you were solving?
- What were the criteria (goals or conditions) that your design had to meet?
- What constraints (limits) to the materials did you have to work with?
- How did you determine which ingredients to use in your prototype?
- How did you measure the success of your prototype?
- How did you improve your formula? What information did you learn that led to your improvements?

On the back of this sheet, work with your child to extend his or her work in the challenge.

This STEM project has been developed in partnership with Texas A&M University.

Hands-On Standards STEM in Action

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Home Connection

As part of your child's work in developing a prototype toy, the team worked with equivalent fractions to scale up their formulas for larger batches. You might think of the formula as a recipe. Have your child explain to you how the example below shows a way to scale up a formula.

Example

The formula for Stretchy Stuff uses 15 mL of glue and 30 mL of liquid starch.

Glue	15 mL	15 mL X 2 = 30 mL
Liquid starch	30 mL	30 mL X 2 = 60 mL
Total volume	45 mL	45 mL X 2 = 90 mL

- What fraction of a single batch is glue?
- What fraction of a double batch is glue?
- Are they equivalent? How do you know?

$$\frac{15\text{ mL}}{45\text{ mL}} = \frac{30\text{ mL}}{90\text{ mL}} = \frac{1}{3}$$

Try it!

Find a recipe for one of your favorite foods. Then make a table to show how to double or triple the recipe. Since most recipes use English units rather than metric units, you will probably need to work with fractions. You may also need to find out how to convert English units such as teaspoons, tablespoons, and cups. Use a cookbook or the Internet to find the conversions.

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Properties of Liquids

Name _____

Follow these steps.

Shape and Volume

1. **Measure** Pour 25 mL of colored water into a graduated cylinder.
2. **Measure** Pour all of the colored water into a small measuring cup. What is the volume of water in the cup?

_____

3. **Analyze** When you poured the colored water from the graduated cylinder to the cup, what happened to its shape?

_____

4. **Analyze** What happened to the volume of the water when it changed containers?

_____

Viscosity

5. **Measure** Pour honey into a test tube until it is 1 centimeter from the top. Screw on the cap.
6. Repeat Step 5 with the corn syrup.
7. **Observe** Tip the honey-filled test tube over and let it sit on its flat top. Start the timer. When the bubble reaches the top, stop the timer.
8. **Measure** How long did it take the bubble to move through the honey?

_____

9. Repeat Step 7 with the corn syrup.
10. **Measure** How long did it take the bubble to move through the corn syrup?

_____

11. **Compare** Which bubble moved more rapidly—the one in the honey or the corn syrup?

_____

12. **Draw conclusions** Which has a higher viscosity—honey or corn syrup? Use evidence to support your conclusion.

_____

Test Big Bouncer

Name _____

Conduct the four tests and record your findings.

Viscosity Test

1. **Measure** How far did the sample flow in 5 minutes? _____

Bounce Test

2. **Measure** How high did the sample bounce? Circle the greatest height.

   Trial 1 _____ Trial 2 _____ Trial 3 _____

Flexibility Test

3. **Measure** How far did the sample stretch without breaking? Circle the greatest length.

   Trial 1 _____ Trial 2 _____ Trial 3 _____

Stickiness

4. **Observe** Did the sample leave a sticky mess on your gloves or other surfaces? Describe what you observed.

   _____

Analyze Data

5. **Analyze** Does Big Bouncer meet the criteria for Sir Isaac's new toy?

   Criteria met: _____

   _____

   Criteria not met: _____

   _____

6. **Evaluate** How could a new toy from Sir Isaac's Toy Company improve on the properties of Big Bouncer?

   _____

   _____

Compare Properties of Mixtures

Name _____

Engineers at Sir Isaac's tested three different mixtures. The table shows the results of their tests. Add the results of your tests on Big Bouncer to the last row.

Test Mixture	Viscosity Test How far did it flow in 5 minutes?	Bounce Test How high did it bounce?	Flexibility Test Did it stretch 30 centimeters?	Stickiness
Slithery Slime • 30 mL glue • 15 mL liquid starch	3.5 cm	Too runny to form a smooth ball	Too runny to form a cylinder	Very sticky
Stretchy Stuff • 15 mL glue • 30 mL liquid starch	0.5 cm	9 cm	Yes	Not sticky
Gummy Goop • 30 mL glue • 2 mL sodium borate	1.5 cm	8 cm	Yes	Sticky
Big Bouncer • 30 mL glue • 10 mL sodium borate				

Analyze Data

1. **Compare** List the mixtures in order of viscosity. (Remember that a material with high viscosity flows *slowly*.)

   1. _____ (most viscous)
   2. _____
   3. _____
   4. _____ (least viscous)

2. **Compare** List the mixtures in order of height bounced.

   1. _____ (highest)
   2. _____
   3. _____
   4. _____ (lowest)

3. **Compare** List the mixtures that stretched 30 centimeters without breaking.

4. **Compare** Which of the mixtures left a sticky residue?

Analyze Results of Tests

Name _____

Review the properties of solids and liquids. Then think about the properties of the four different mixtures.

1. **Classify** How are the four mixtures like liquids? Give two examples.

2. **Classify** How were these mixtures like solids? Give an example.

3. **Analyze** When they were stressed by rolling and pulling, did the mixtures become more or less viscous?

   Give two examples.

4. **Draw conclusions** Are the four mixtures Newtonian or non-Newtonian fluids? Explain.

Analyze Results of Tests
(continued)

Name _____

Remember Sir Isaac's criteria. The new toy must:

- ☑ Flow at least 1 centimeter in 5 minutes
- ☑ Bounce at least 7 centimeters
- ☑ Stretch at least 30 centimeters without breaking apart
- ☑ Not leave a sticky mess.

5. **Analyze** Which mixtures met the criteria for flowing?

   _____

   What did you notice about the ingredients of these mixtures?

   _____

6. **Compare** the test results for Big Bouncer and Gummy Goop. Which was more viscous (flowed more slowly)? _____

7. **Draw conclusions** Compare the formulas of Big Bouncer and Gummy Goop. How does increasing the amount of sodium borate in a formula affect the viscosity of the mixture?

   _____

8. **Analyze** Which mixtures met Sir Isaac's criteria for bouncing?

   _____

   Which ingredient seems to increase the bounciness?

   _____

9. **Analyze** Which mixtures met the criteria for stretching?

   _____

   Which ingredient seems to limit stretching?

   _____

10. **Analyze** Which mixtures were sticky?

    _____

    What was the main ingredient in each of these mixtures?

    _____

Scaling Up

Name _____

Use the quantities in the table to answer the following questions.

Use what you know about scaling up to calculate the quantities of ingredients needed to make double and triple batches of each formulation. Then complete the table.

Ingredients	Number of Batches		
	1	2	3
Slithery Slime			
glue	30 mL		
liquid starch	15 mL		
Stretchy Stuff			
glue	15 mL	30 mL	
liquid starch	30 mL	60 mL	
Gummy Goop			
glue	30 mL		
sodium borate	2 mL		
Big Bouncer			
glue	30 mL		
sodium borate	10 mL		

1. In Slithery Slime, what fraction of a double batch is liquid starch? _____
2. In Gummy Goop, what fraction of a double batch is glue? _____
3. In Big Bouncer, what fraction of a triple batch is sodium borate? _____
4. **Analyze** How much glue do you need to make a liter of Gummy Goop? Show your work.

Toy Plan

Name _____

Use these questions to develop the formula of your new toy.

1. Which ingredients will you use? List them in the table.

2. What property or properties do you think each ingredient will give to your final product? List them in the table.

Properties of Ingredients	
Ingredient	**Properties**

3. How much of each ingredient will you use? Write it in the table below. Be sure your total quantity is within the constraints of the problem.

Formula	
Ingredient	**Quantity (mL)**
Total volume of ingredients	

Remember one of your constraints: Your formula may use no more than 20 mL of sodium borate.

Compare Weights
Answer these questions as you make your prototype.

4. **Measure** What was the total weight of the measuring equipment and all the ingredients before they were mixed together? _____

5. **Measure** What was the total weight of the measuring equipment and the final mixture?

_____

6. **Compare** the weight of the ingredients and final mixture. Which weighs more?

_____

7. **Analyze** Why did you get the results you did from the two weight measurements?

_____

Test the Prototype

Name _____

Conduct the following tests.

Volume

1. **Measure** What is the total volume of your mixture? _____

Viscosity Test

1. Put on gloves. Use enough of the mixture to make a ball with a diameter of 3 centimeters.
2. Place the ball in the center of the circle on the flow measurement sheet.
3. Start the timer.
4. After 5 minutes, stop the timer.
5. **Measure** How far did the ball flow? _____

Bounce Test

1. Lay a piece of wax paper on a table.
2. Use enough of your mixture to make a ball with a diameter of 3 centimeters. Roll it so it is very smooth.
3. **Measure** Hold up a ruler. Hold the ball 15 centimeters above the desk. Drop the ball on the wax paper. Observe how high the ball bounces.
4. Repeat the test three times. What was the highest bounce? _____

Flexibility Test

1. **Measure** On the wax paper, roll your mixture into a cylinder that is 1 cm in diameter and 8 cm long. If the cylinder is too long, cut it to the correct length.
2. Lay the measuring tape across the table. Hold the ends of the cylinder and gently stretch it. The cylinder should not break or fall apart.
3. **Calculate** the length of the cylinder. Subtract 8 centimeters from the length after stretching. This is the total amount stretched.
4. Repeat the test three times.

Trial	Length After Stretching	Total Amount Stretched
1		
2		
3		
4		

5. **Analyze** What was the greatest distance stretched? _____

Stickiness

1. Did your prototype leave a sticky residue or attract dirt? _____

Reflect On It

Name _____

Use your team's Toy Plan and Test the Prototype pages to finish these sentences.

Formula

1. The ingredients in our formula are _____

_____

2. We chose each ingredient because _____

_____

_____

_____

Prototype

3. Our prototype met these criteria: _____

_____

4. Our prototype stayed within these constraints: _____

_____

Compare Prototypes

5. We compared our prototype to Team _____. I observed that _____

_____

_____

6. The most successful prototype was made by Team _____. It may have been most successful because _____

_____

_____

_____

_____

_____

Compare Prototypes

Name _____

Prototype and Ingredients	**Viscosity Test** How far did it flow in 5 minutes?	**Bounce Test** How high did it bounce?	**Flexibility Test** Did it stretch 30 centimeters?	**Stickiness**

Analyze Data

1. **Compare** List the prototypes in order of viscosity. (Remember that a material with high viscosity flows *slowly*.)

   1. _____ (most viscous)
   2. _____
   3. _____
   4. _____
   5. _____
   6. _____ (least viscous)

2. **Compare** List the prototypes in order of height bounced.

   1. _____ (highest)
   2. _____
   3. _____
   4. _____
   5. _____
   6. _____ (lowest)

3. **Apply** Which prototype was the stickiest? What do you think made it so sticky?

_____

_____

_____