Grades 4-8

MEASUREMENT AND OBSERVATION
A “taste” of Quantum

LEARNING OBJECTIVES
Students will be able to:
• distinguish between destructive and non-destructive measurements.
• explain the difference in measurement and observation.
• determine when a change occurs while being measured.

NGSS ALIGNMENT
DCI: 5-PS1-3 Make observations and measurements to identify materials based on their properties.
SEPS: Plan and carry out investigations to answer questions; Carry out investigations that control variables.
CCC: Standard units are used to measure and describe physical quantities.
3-5-ETS1-2 Engineering Design: Generate and compare multiple solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

MATERIALS
• Assorted Jelly Belly beans
• Towels, wipes, plates, napkins
• Chart paper or whiteboards

BACKGROUND
Measurement can be accomplished in different ways. Traditional measurement tools include rulers, scales, thermometers, etc., however, there are new and different ways to measure.

When students study something in nature, they are typically asked to observe the object. To observe means to use your senses to describe an object or phenomena and record those observations. Traditionally we measure a book using a ruler, which assigns a number to the dimensions of the book and the measurement is the same before and after we measure it.

Sometimes, however, observations or actions can change the object being measured. If someone observed a Tootsie Pop®, they could estimate how many licks it would take to get to the center. To test the claim, one would lick the Tootsie Pop® while counting the licks, gathering evidence and data. However, as someone licked the Tootsie Pop®, they changed it, so the change is a new measurement, and it is no longer what it was originally.

Traditionally, this change would be measured with tools, but in this case, tools are not used to measured it, we want to just “know it changed” through observations. Students can record observable evidence of the change to support their claim.

In science, an observation may change the object when observed. For example, if a coin is tossed in the air and someone asked if it was heads or tails, one would have to say both until someone “observed” how the coin landed. While the coin is in the air, it IS both heads and
tails. When you “observe” how it landed, the coin is no longer both, but is either heads or tails. The process of observing, or trying to measure what the coin was, changed the coin (i.e. from both to either heads or tails).

**ENGAGE/PHENOMENA**
Jellybeans are supposed to be a candy that is tastes good when eaten. However, in the *Harry Potter* movie there is discussion regarding Bertie Bott’s Jelly Bellies because some of them DON’T taste so great! To avoid an experience that results in never wanting to taste another jelly belly, it might be beneficial to have a way to test the flavor before it is eaten.

Watch the clip from Harry Potter: [https://youtu.be/CtwABtCqecA](https://youtu.be/CtwABtCqecA)
Consider reading or having available one or more of the following: *Inch by Inch* by Leo Lionni, *The Three Little Pigs, Goldilocks and the Three Bears*. Characters in these stories measure various items such as the length of a bird’s tail, the temperature of soup, and the strength of a house.

- Have students identify the measurement tools used in these stories.
- Chart their answers (this chart can be use later for comparison or to determine if these measurements were destructive or not)

**INTRUSIVE & NON-INTRUSIVE MEASUREMENT**
Remind students that they can use their senses to measure an object or phenomena.

- Show students the jellybeans and tell them that they are going to be able to eat some jellybeans, but not yet.
- Facilitate a discussion of the question: “If someone gave you a jellybean, how could you determine (measure) what flavor a jellybean it is?”

It is often important for the method of measurement to not “intrude” (i.e. not interfere or change the actual jellybean, it is the same before and after you measure it) on what you are measuring.

- Encourage students to come up with at least four ways to measure the flavor of a jellybean without being intrusive (i.e. method is non-destructive).
- Have students share out into the larger group and chart their answers as nonintrusive measurements.

Ask the students if all jellybeans of the same color will have the same flavor (e.g. if it is yellow does it have to be lemon?).

- Discuss and ask guiding questions to help lead them to the idea that there may be different flavors that are the same color.
- Tell students they can be “intrusive” (i.e. the jellybean will change or be destroyed) to take measurements and ask how they can measure the flavor of the jellybean.
- Chart the student responses and identify them as intrusive/destructive.
- Compare the different methods of measurement. Why were some intrusive/destructive and some nonintrusive/nondestructive?
Give students two jellybeans that are the same color. Some can be the same flavor, some different.

- Discuss which method of measurement would be best to determine their flavors.
- Facilitate a discussion of which methods are destructive and which are not destructive (i.e. they change during the method being used).
- Have students explain the method of measurement they selected and justify their answer.
  - Why do you think the method you chose would or would not work?
  - Does this method have any problems or challenges?
  - In order to know the flavor of two jellybeans that are the same color, would you need to test both jellybeans? Explain.

**EXPLORE**

Give each student a Measurement worksheet and some jellybeans. The worksheet could also be recreated on a whiteboard, chart paper, etc. for group discussion.

Have each student or group test a jellybean using one method of measurement at a time starting with the non-destructive methods before using the destructive methods.

After each measurement, have students record their thoughts on the worksheet or in a journal. They should record what they think the flavor is, which might be a change from their previous thought based on the new information from the current measurement. Students should also record why they selected flavor (i.e. make a claim) and indicate how confident they are in selecting that flavor based on their evidence.

<table>
<thead>
<tr>
<th>Color</th>
<th>Possible Flavors</th>
</tr>
</thead>
<tbody>
<tr>
<td>RED</td>
<td>Cinnamon, Cherry, Red Apple, Strawberry, Raspberry</td>
</tr>
<tr>
<td>ORANGE</td>
<td>Orange, Peach, Cantaloupe, Grapefruit</td>
</tr>
<tr>
<td>YELLOW</td>
<td>Lemon, Pineapple, Popcorn</td>
</tr>
<tr>
<td>GREEN</td>
<td>Green apple, Kiwi, Lime, Watermelon</td>
</tr>
</tbody>
</table>

After students have tried all the measurement methods on one jellybean, they should try them again with a jellybean of a different color. **Be sure they always record their data.**

Each student should try all methods with at least 2 jellybeans, depending on time, and record their results.

After testing two or more jellybeans, have participants respond to the worksheet prompt, “Which method do you think is best for figuring out the flavor of a jellybean? Justify your answer.
SAMPLE DATA TABLE

<table>
<thead>
<tr>
<th>Method</th>
<th>Destructive/ Non-Destructive (Circle One)</th>
<th>Claim</th>
<th>Evidence</th>
<th>Reasoning</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Look</td>
<td>Destructive</td>
<td>What flavor do you think it is?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smell</td>
<td>Destructive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Break Open &amp; Smell</td>
<td>Destructive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eat</td>
<td>Destructive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Destructive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EXPLAIN**

Have students discuss what they learned from the Explore. Guide students to the idea that measuring something about an object can change it.

Students should be able to justify the following questions based on their evidence.

- **Identify the method(s) used to get the same results each trial? What are the pros and cons of this method?**
- **How much information did you gain about the jellybeans by using non-destructive methods (i.e looking, smelling)?**
- **How much information did you gain about the jellybeans by using destructive methods (i.e breaking open and smelling, tasting)?**
- **Can you think of other times when something is measured and it changes? Explain your answer with examples.**
EXTEND
It is quite common for teachers to use jellybeans as an observation activity in elementary, but the intent of the activity is to help students understand a non-traditional way to observe is through measurement. However, in quantum information science, measuring is not just using traditional tools, but has some inherent challenges yet to be resolved.

One example of such a challenge is in computing. Current computers use a simple on/off, 0 or 1 system to communicate. For example, when you type on the keyboard, the computer key sends a signal to the computer, which is translated as “on” or “off” (which can also be 0 or 1 or any other coding system you want). However, quantum computers are different from our current computers in that they use a more complex system. In quantum computers, it is not a 0 or a 1, but it can be both at once, similar to the coin being heads and tails.

A major challenge for the engineers and scientists is to design a device that is non-destructive (i.e. does not change or destroy) when trying to measure whether it is a 0 or a 1 (e.g. head or tail). All current measuring devices for computers only measure whether it is a 0 or 1. They are considered destructive because they cannot tell us what it was before it was measured.

As soon someone tries to measure something on the quantum level, the very event/entity being measured changes. This means one does not have the original “thing” they were trying to measure. Before measuring a quantum jellybean, quantum physicists would say a quantum yellow jellybean is pineapple, popcorn AND lemon at the same time.

- What would they say about a red quantum jellybean?
- Have students discuss how this is counterintuitive to our current method of measuring.
- What engineering challenges can you identify?

EVALUATE
Ask students to explain the difference in observing and measuring the jellybeans.

- What were they measuring?
- How did they measure it? Why did they measure it that way?
- Did it change at all when they measured it?

Have students explain measuring with tools vs measuring with observations.

Ask students to give examples and distinguish between destructive and non-destructive methods based on their evidence from the jellybean experiments.

- What method was destructive? What method was non-destructive?

Chart Traditional/Standard/non-destructive Measurements vs. Destructive Measurements