

Training for Educators

Entanglement

Primary Level

Ages 5-11

Purpose of the lab

- The purpose of this lab kit is to introduce quantum entanglement through activities and experiments. Students will think about how entangled particles that are in superposition can then be measured to understand information about both particles instantly, no matter how far apart they are. This will be demonstrated analogously with balloons and balls using two different ways of “measuring”.
- The main takeaways are:
 - Superposition means that an object can exist in multiple states at once.
 - Entangled objects are linked such that knowing something about one of them gives information about the other instantly.
 - Measurement of a system forces the objects to be in definite states.

Summary of experiments



There are 2 activities and one design challenge.

Supplies list

- Two colors of balloons (like red and blue)
- Opaque bags (like black trash bags)
- String or tape (to tie or attach the balloons)
- Identical cups
- Two types of balls that have very different weights (like metal and plastic)
- Marker
- Fabric (as a blindfold)
- Scale (optional)

Safety considerations

Before the students begin the laboratory, please take into consideration the following safety concerns:

- Small items like balls can be a choking hazard, so avoid putting them in your mouth.
- Students should handle balloons carefully to avoid popping them, which can cause minor injury.
- If moving to different locations or behind a divider, especially when blindfolded, be mindful of obstacles to prevent accidents.
- Always do activities under teacher supervision.

Setting up your space

- Gather your supplies and separate by experiment(s) on your table.
- These are our recommendations:
 - Each student should have a pencil or pen.

Groups of 2-4 students can be given the following supplies:

- 2 balloons of different colors
- 2 opaque bags
- 2 lengths of string or tape
- 2 identical cups
- 2 balls of very different weights
- Fabric (as a blindfold)

The class can share the following supplies:

- Markers
- Scale (optional)

Part I. "Measuring" by seeing

- Set-up:
 - Each group (2-4 students) will need 2 different colored balloons, 2 opaque bags, and string/tape.
- Procedure:
 - After one student places one balloon each into two bags without others seeing, students will take out one of the balloons and race to say which color of balloon is in the other bag.
- Results
 - Students should see that by knowing one of the balloon colors allows them to know the other instantly.

The takeaway is the "entangled" balloons are being used to demonstrate superposition, and by "measuring" one balloon by sight, you instantly know something about the other balloon.

Part II. "Measuring" by feeling

- Set-up:
 - Each group of 2-4 students gets 2 cups, two types of balls that have very different weights, and fabric for blindfold.
- Procedure:
 - Blindfolded students should guess which of the two balls is in the cup they are holding, as well as in the cup they are not holding.
- Results:
 - Students will see that by making a "measurement" on the ball in the cup they are holding, they can know which ball is in the other cup (as long as they make the correct guess first).

The takeaway is the "entangled" balls are being used to demonstrate superposition, and by "measuring" one ball by feel, you instantly know something about the other ball.

Design challenge

Students are asked to design a device that uses entanglement to do something useful. You can pretend that quantum mechanical behavior such as entanglement extends to large objects around you (like balloons, cups, balls, etc.).

- Questions to ask the students (encourage creativity)
 - What could entanglement and superposition be useful for in the real world (you can pretend that entanglement and superposition extend to large objects around you)? Be creative and think broadly.
 - What will you use entanglement and superposition for in your tool or machine?
 - What kinds of materials will you need to create your tool or machine?