Plinko Probability

Explore how to manipulate probability distributions

Learning Goals
- Understand that doing the same thing can result in different outcomes.
- We can make changes to alter the chances of a certain outcome happening

Importance in Quantum Computing
Quantum bits, or qubits, have the probability of being measured as one of multiple different states. Some states are more likely to be measured than others.

Materials (per group)
- ❏ Cardboard/cereal box
- ❏ Glue or tape
- ❏ Push pins
- ❏ Scissors
- ❏ Paper
- ❏ Pen/marker
- ❏ Pennies or similarly shaped objects

Preparation
- Print one copy of the accompanying worksheet for each group.
- Gather materials for each group.
- Read DIY instructions below.

Background Knowledge

We expect that when we do the same task (such as measuring the length of a table) multiple times, we will always get the same result. But sometimes doing the same thing over and over again yields different results each time. For example, when you flip a coin you flip it the same way each time but you don't always get the same result. It's important to understand how many times we expect the coin to land each way. This is called the *probability* or the chances of getting each result. If we flip a coin 100 times we would expect that the coin would land heads-up approximately 50 times, however we cannot predict the exact outcome of each individual flip. In quantum computing, there is something called a quantum bit, or qubit. Instead of storing a single value like in a classical computer, it stores two values, with a probability of reading each one (just like the heads/tails of the flipping coin). And, like the coin, it is only when the qubit is measured that we get one or other value (like when the coin lands). A plinko game has not only this probabilistic nature of flipping a coin, but the ability to change the probability of each outcome.

Facilitating the Activity
ENGAGE

1. Consider reading or having available *That's a Possibility* by Bruce Goldstone

   This book introduces basic vocabulary associated with probability such as **certain**, **probable**, **impossible**, and **percentages.** The text also elaborates on the coin toss analogy and asks questions to students about the possibility of particular outcomes in a coin toss.

ACTIVITY

1. Show a video of someone playing a Plinko-style game
   i. **Ask:** What do you think affects where the balls/coins/etc land?
      Ask: What could you do to change where the balls land?/ How would you get more balls to fall in one bin compared to another bin?
2. Group participants into groups of 3-4, distribute materials to each group, and supply them with the DIY Plinko instructional page provided below.
   a. Alternatively, if there are enough supplies for each participant, this can be conducted as an individual activity.
3. Have each group assemble their box.
   a. *Optional:* Have each group set up their box differently (different pin placement, different bin size, etc.) to see how it affects the resulting probability distribution.
4. Have the participants make an organizational tool (e.g., data table) of their own to use during the activity. Alternatively, you can use or modify the organization tool that is provided below such that it is appropriate for your students.
   a. Using their organizational tool:
      i. Have the participants **make predictions** about the distribution of where the pennies will land.
      ii. As a part of their predictions, have them explain why they think the pennies will land how they described in part i.
5. Have each group drop their pennies down the side of their box, recording where each penny lands. Repeat the same procedure for 10 pennies.

a. During this time, make sure the groups are dropping the pennies from the same location on the top. Changing where you drop the pennies from changes the probability of where they will land.

b. If time permits, have the groups do 1-2 more trials (1 trial = 10 penny drops). See if the distribution is the same or different for each trial.

6. **Extension:** Keeping the bins in the same location on the box, change the location of the pins (add more, take some away, change their location, etc.) and repeat the exercise. Alternatively, change the size of the bins that the pennies land in.

   a. **Ask**: How was this different from your original set-up? How did this change affect where the pennies landed?

DISCUSSION

1. Facilitate a discussion about probability distributions. **Ask** questions such as:
   a. In your original set-up with evenly distributed pegs, where did the penny land the most often? The least often?
   b. What methods did you use to change where the pennies would land? If you tried multiple different methods, compare and contrast the results.
   c. If you wanted to make the pennies land to the left more often, what methods could you try to make that happen?
   d. How hard was it to control the probability distribution? How hard was it to get all of the pennies to land on the left?

2. Tell participants that qubits are like coins or dice, in the sense that when we measure the qubit (roll the dice or toss a coin) the qubit ends up as only one value (like a 4 ona die or heads on a coin). But unlike the dice or coin a qubit doesn't always have equal chances of landing on a 0 or 1 (1-6 or heads or tails). Qubits can be changed so that it is more **probable** to get a particular outcome. The chances of getting a 0 or 1 is called the **probability distribution**, or how likely it is to get each value.
   a. **Ask:** How does this relate to the activity that we did with the plinko game?
   b. **Ask:** How could you change a coin to increase your chances of it landing heads up?
   c. **Ask**: What are some reasons you would want to increase the outcome of a coin toss?

Connections to Standards

Next Generation Science Standards*

Crosscutting Concepts: Cause and Effect, Stability and Change
Science and Engineering Practices: Planning and Carrying Out Investigations, Using Mathematics and Computational Thinking

Common Core State Standards

Standards for Mathematical Practice: Construct Viable Arguments and Critique the Reasoning of Others, Use Appropriate Tools Strategically

More Quantum Computing Resources from EPiQC

https://www.epiqc.cs.uchicago.edu/resources

Acknowledgements

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Organizational Tool Sample:

Place tally marks to count where the pennies land			
A	**B**	**C**	**D**

DIY Plinko Assembly Instructions

Materials

- ❏ Cardboard/Cereal box
- ❏ Glue or tape
- ❏ Push pins
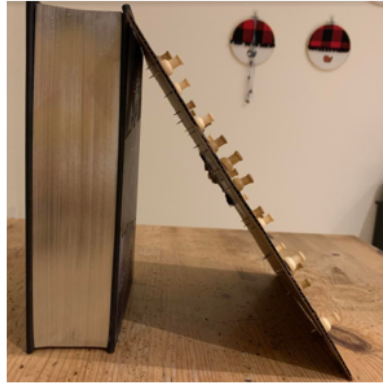- ❏ Scissors
- ❏ Paper
- ❏ Pen/Marker
- ❏ Pennies or similarly shaped objects

How to Build It

Step 1:	**Step 2:**	**Step 3:**
Evenly distribute your pins in the cardboard sheet.	Make a ramp by leaning the cardboard (with pins) against something sturdy, like a stack of books.	Divide your piece of paper into equal sized sections along one edge. Place the piece of paper at the end of the ramp.