

Lesson Title: The Galton Board and Science

Grade Level:

5th – 12th grade

Content Objectives: Students will be able to build models of atoms that create foam board.

Students will be able to classify solid, liquids, and gases through an interactive notebook page.

Language Objectives: Students will be able to identify the different types of atoms in the models they built.

Students will be able to explain the similarities and differences between solid, liquids, and gases.

Vocabulary:

- Molecule
- Polystyrene
- Solid
- Liquid
- Gas

Next Generation State Standard(s):

5-PS1-4 – PS1.B: When two or more different substances are mixed, a new substance with different properties may be formed.

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)

Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.

- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS-PS2-3)

Materials:

- *Galton Board: Math in Motion*

Middle School

- White construction paper

- Marker or crayons
- Glue

High School

- Molecular Model Kits
- If you don't have a kit, use construction paper
 - o White construction paper (hydrogen)
 - o Black construction paper (carbon)
 - o Glue
 - o Scissors

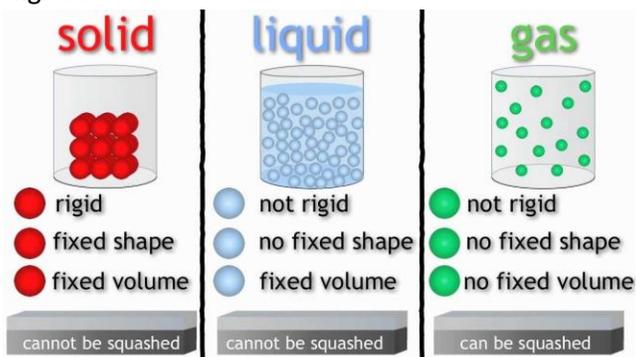
Preparation:

- Printed copies of the Galton Board rubric
- Gather materials
- Load Youtube videos:
 - o <https://www.youtube.com/watch?v=6YDHBfVlvs&t=26s>
 - o <https://www.youtube.com/watch?v=TYya2uPFvzo>
- Molecular Model Student Kit: <https://www.amazon.com/Duluth-Labs-Organic-Chemistry-Molecular/dp/B016ZAWAIS>

Lesson:

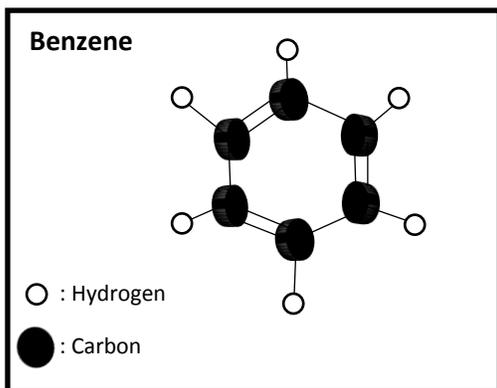
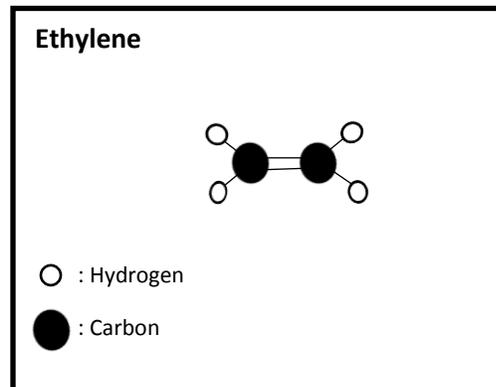
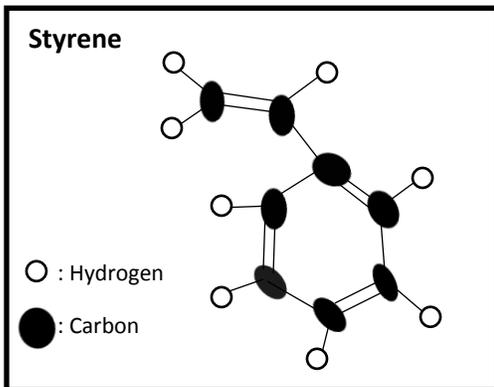
- Introduce the Galton Board by passing out the *Galton Board: Math in Motion* product.
- Provide students with time to use this product and be ready to discuss the following questions:
 - o What are you observing when you flip the Galton Board and the beads fall into the bin?
 - Answer Examples: There is an equal chance of the bead bouncing left or right; the beads tend to fill towards the middle.
 - o What mathematical topics are connected to the Galton Board?
 - Answer Examples: Bell curve (normal distribution); probability; Pascal's Triangle; Binomial coefficients; Powers of 2; Powers of 11; Square Numbers; Prime Numbers; Fibonacci Sequence; Sum of Squares. **For this unit focus will be:** Middle School (Bell curve; prime numbers; square numbers; powers of 11 (expanded notation) and High School (Normal distribution; Fibonacci sequence; Triangular numbers; Binomial coefficients).
 - o What careers connect to these mathematical topics?
 - Market Research Analyst; Meteorologist; Statistician; Operations Research Analyst; Financial Analyst; Ecological/Environmental Statistics; Educational Testing and Measurement; Environmental Health Sciences; Government Service. <https://www.ma.utexas.edu/users/mks/statund/careers.html> will provide you with further information on each of these careers.
- Watch Galton Board YouTube video to reinforce ideas just discussed:
 - o <https://www.youtube.com/watch?v=6YDHBfVlvs&t=26s>
- Purpose of learning the basics of the Galton Board is for students to create their own board and understand the basic concepts of probability (Middle School) or develop their understanding further of Law of Numbers (High School).

- If you'd like, pass out the rubric for the Galton Board that will provide a structured vision for the board. If you would like to challenge students, have students develop expectations.
- Students will develop their Galton Board using Foam board. Watch YouTube video to show the science behind the foam board.
- Youtube video: How is expanded polystyrene produced?
<https://www.youtube.com/watch?v=TYya2uPFvzo>
- This process helps to develop your foam boards that are covered with a white paper and used for posters or presentations.
- Middle School: Students create drawings that show what molecules look like when in solid, liquid, and gas form. If you would like to challenge students further, look at the concepts for High School.



States of Matter (solids, liquids and gases) | The Chemistry Journey | The Fuse School - YouTube

- Students will fold their page into thirds. At the top of each portion, students will provide a title that is solid, liquid, or gas. For each section, students draw what the molecules look like in the state and describe the movement of the molecules. Students can provide other characteristics as well.
- They can glue their paper into their notebook.
- High School: Pass out molecular models for students to create a 3D molecule. If you don't have a set you can order them or cut circles in different colors (2D model).
 - Molecular Model Student Kit: <https://www.amazon.com/Duluth-Labs-Organic-Chemistry-Molecular/dp/B016ZAWAIS>
 - Colored Paper:
 - Carbon – black paper
 - Hydrogen – white paper
- Molecule Structures:
 - Styrene (C₈H₈)
 - Styrene is created from natural gas formed by a reaction between Ethylene (C₂H₄) and Benzene (C₆H₆).
- Provide students with these molecule structures and have them try to build the molecules on their own and discuss how they believe the molecule is structured.



- Groups can present their work to strengthen their soft skills.

Check for Understanding:

Middle School: Solid, liquid, and gas interactive notebook page.

High School: 3D molecules of chemicals.

Lesson Title: Galton Board and Mathematics

Grade Level:

6th -12th Grade

Content Objectives: Students will be able to use Pascal’s Triangle to identify mathematical concepts.

Language Objectives: Students will be able to summarize the mathematical concepts they identified.

Vocabulary:

- Pascal’s Triangle
- Prime Numbers
- Square Numbers
- Fibonacci’s numbers
- Triangular Numbers
- Binomial Coefficients

Common Core State Standard(s):

- CCSS.MATH.CONTENT.6.EE.A.1
- CCSS.MATH.CONTENT.6.EE.A.2.B
- CCSS.MATH.CONTENT.7.EE.A.1
- CCSS.MATH.CONTENT.HSA.APR.C.5
- CCSS.MATH.CONTENT.HSA.SSE.A.1.A
- CCSS.MATH.CONTENT.HSA.SSE.A.1.B
- CCSS.MATH.CONTENT.HSA.SSE.A.2

Materials:

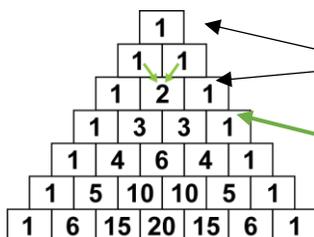
- Pascal’s Triangle half sheet (Middle School)
- Pascal’s Triangle half sheet (High School)

Preparation:

- Print and cut the Pascal’s Triangle half sheet
- Load YouTube video
 - o <https://www.youtube.com/watch?v=XMriWTVPXHI&t=3s>

Part 1: Pascal’s Triangle Lesson

- Discuss with students what they already know about Pascal’s Triangle and what they want to know about Pascal’s Triangle.
- Next, introduce Pascal’s Triangle by watching: The mathematical secrets of Pascal’s Triangle – Wajdi Mohamed Ratemi.
- <https://www.youtube.com/watch?v=XMriWTVPXHI&t=3s>
- The Pascal Triangle will help students when building their Galton Board
- Pass out interactive notebook, half sheet of Pascal’s Triangle. Students fill out the triangle with the required numbers. See below. Do the students remember how they can fill out the triangle?
- **Teacher answers are below.**



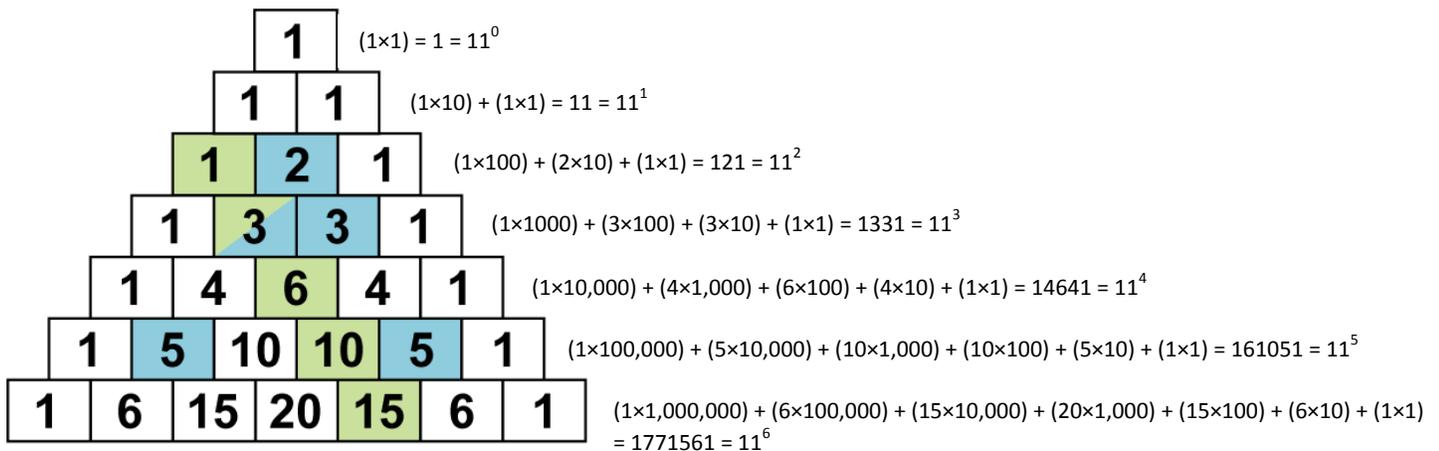
Start with 1 at the top. Remember $1+0= 1$, hence why there is a 1 below and with the box next to it.

Add the pair of two boxes to get the answer for the box below. Example $1 + 1 = 2$.

- Have students turn to a partner and discuss what patterns or mathematical concepts they can find with the triangle. Discuss this as a class when complete.

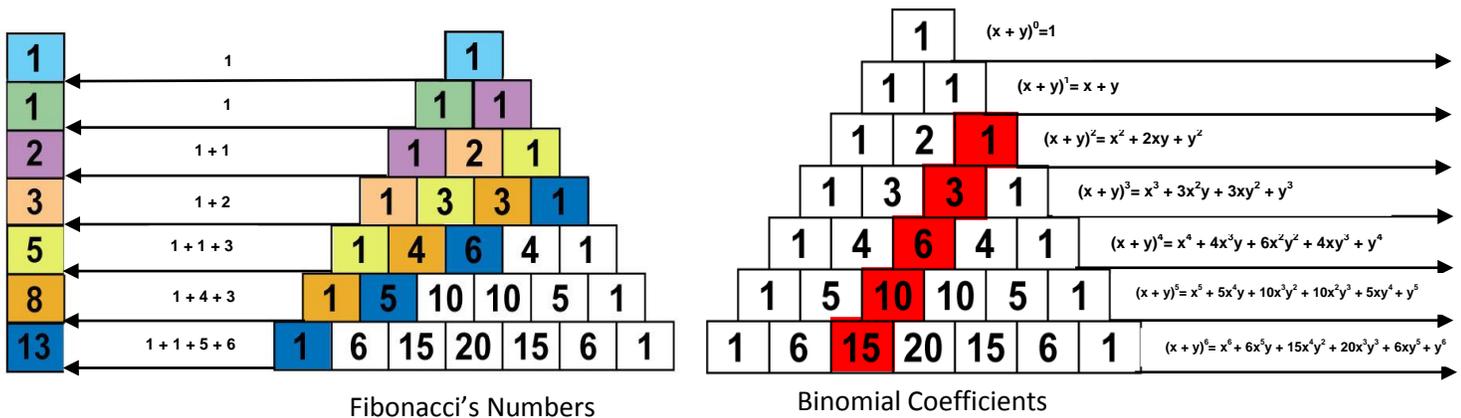
Middle School Concepts

- Students will need two different colors to locate mathematical concepts on the Pascal Triangle.
 - o Blue – Prime Numbers
 - o Green – Square Numbers ($1 + 0 = 1 = 1^2$; $1 + 3 = 4 = 2^2$; $3 + 6 = 9 = 3^2$; $6 + 10 = 16 = 4^2$)
 - o Powers of 11: For this, students will also write down the expanded notation in line to the row.
 - o **Teacher answers are below.**



High School Concepts

- Students will need different colors to locate mathematical concepts on the pascal triangle.
 - o See figure – Fibonacci's numbers
 - o Red – Triangular Numbers
 - o Binomial Coefficients: For this, students will write their answers in line with the row.
 - o **Teacher answers are below.**



- Students summarize their findings, once complete.

Check for Understanding:

Middle School: Pascal Triangle interactive notebook (prime numbers, square numbers, and powers of 11)

High School: Pascal Triangle interactive notebook (Fibonacci's numbers, triangular numbers, and binomial coefficients)

Lesson Title: Galton Board and Technology

Grade Level:

6th -12th Grade

Content Objectives: Students will be able to predict, observe, and analyze data using the Galton Board.

Language Objectives: Students will be able to use technology to support them when analyzing data.

Vocabulary:

- Mean
- Bell Curve
- Total Area
- Symmetry
- Standard Deviation
- Normal Distribution

Next Generation State Standard(s):

MS-ETS1-3

Common Core State Standard(s):

CCSS.MATH.CONTENT.6.SP.B.5.A

CCSS.MATH.CONTENT.7.SP.B.4

CCSS.MATH.CONTENT.HSS.ID.A.4

CCSS.MATH.CONTENT.6.SP.A.2

CCSS.MATH.CONTENT.7.SP.C.8

CCSS.MATH.CONTENT.HSS.IC.B.6

CCSS.MATH.CONTENT.6.SP.B.5.C

CCSS.MATH.CONTENT.HSS.ID.A.2

RST.11-12.8

CCSS.MATH.CONTENT.7.SP.A.2

CCSS.MATH.CONTENT.HSS.ID.A.3

RST.6-8.7

RST.6-8.9

ISTE Standard(s):

2.DIGITALCITIZEN.B

5.COMPUTATIONALTHINK.B

7.GLOBALCOLLABORATOR.C

Materials:

- Galton Board: Math in Motion
- Path Predictions worksheet
- Smartphone or video camera
- Colored pencils or markers
- Bell Curve interactive notebook page

Preparation:

- Make copies of Path Predictions
- Make copies of Bell Curve interactive notebook page
- Load Youtube videos
 - o <https://www.youtube.com/watch?v=gV1gUdFvI54>
 - o <https://www.youtube.com/watch?v=c11d3vVM5v8>
- May need to locate video cameras, if students do not have Smartphones

Lesson:

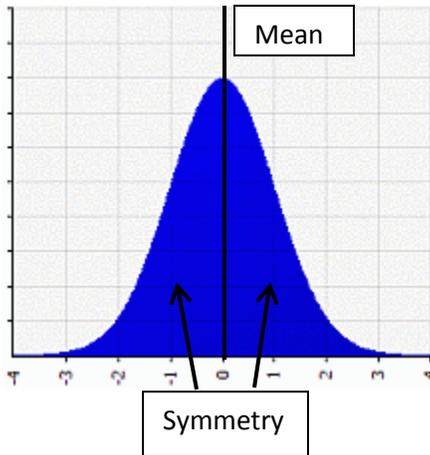
Part 1: Path Predictions

- Pass out Galton Board: Math in Motion.
- Pass out Path Predictions sheet (can use for high school).
- Students will need their Smartphone or video camera to record and slow down a recording.
- Before students begin their observations, they will discuss predictions first.
 - o Do students believe they can predict the path of the beads? Why or why not?
 - o Is it nearly impossible to predict the beads paths? Why or why not?
- Students will then write down their predictions onto their Path Predictions sheet.
- Discuss how, in pairs, one student will record the beads, while one student flips the Galton Board to have the beads fall through its Pascal Triangle.
- When recording, students will need to record until all beads fall and you are able to see where they fell.
- After students are done recording, they will slow down the video camera and observe how the beads fall. They will pick out beads to trace their path onto their Path Predictions sheet.
- Have students put their Path Predictions sheet and Galton Board aside before moving on to Part 2.

Part 2: Normal Distribution

Middle School:

- Pass out Bell Curve interactive notebook page
- Begin by watching Normal Curve – Bell Curve – Standard Deviation – What Does it All Mean?
- <https://www.youtube.com/watch?v=gV1gUdFvI54>
- The focus is there is an equal chance for the bead to fall left or right, this creates the bell-shaped curve.
- In the video, there is the example of the bell curve showing the average IQ. Students brainstorm other concepts the bell curve can show. **Example:** Heights, weights, and exam scores.
- Students will need their Path Predictions sheet and their Galton Board again.
- This time when they flip their board, they watch the beads collected below and create a bell-shaped curve.
- Students draw the bell-shaped curve that was created and label the parts of the curve from the video they watched. Each row in the curve can be shaded a different color to help see each row.
 - o Label:
 - Where the mean is located
 - Where the symmetry is
- Teachers can enhance this activity by implementing math concepts that students have already learned.
- Teachers then have students calculate the mean of their bell-shaped curve. Students may know that by finding the middle of the bell-curve, this will show them the mean, median, and mode.



Statistics How To

<http://www.statisticshowto.com/bell-curve/>

- Students can also find mean by counting how many beads are in each row, add up all the final numbers per each row, and then divide by how many rows there are.

High School:

- Pass out Bell Curve interactive notebook page
- Begin by watching Stats: What is a “Standard Normal Distribution”?
- <https://www.youtube.com/watch?v=c11d3vVM5v8>
- The focus is there is an equal chance for the bead to fall left or right; this creates the bell-shaped curve.
- Students will need their Path Predictions sheet and their Galton Board again.
- This time when they flip their board, they watch the beads collected below and create a bell-shaped curve.
- Students draw the bell-shaped curve that was created and label the parts of the curve from the video they watched. Each row in the curve can be shaded a different color to help see each row.
 - o Label:
 - Shade the Total Area. What number is this equal to?
 - Where the symmetry?

Probability

- Once students have drawn and labeled their bell-shaped curve, you can enhance this lesson with high schoolers implementing probability.
- Youtube video: Stats: Finding Probability Using a Normal Distribution Table
- Resources:
 - o Probability: Part 2 (Distributions) by Michael T. Schmidt
 - o <http://www.thephysicsmill.com/2014/04/13/probability-part-2-distributions/>
 - o Quincunx Explained by Math is Fun
 - o <http://www.mathsisfun.com/data/quincunx-explained.html>

Check for Understanding:

Path Predictions

Lesson Title: Engineering Your Own Galton Board

Grade Level:

6th – 12th Grade

Content Objectives: Students will be able to build their own Galton Board model using the knowledge they've obtain throughout this unit.

Language Objectives: Students will be able to explain the mathematical concepts that the Galton Board reinforces.

Vocabulary:

- Mean
- Bell Curve
- Prime Numbers
- Square Numbers
- Fibonacci's numbers
- Symmetry
- Standard Deviation
- Normal Distribution
- Triangular Numbers
- Binomial Coefficients

Next Generation State Standards(s):

HS-ETS1-2

MS-ETS1-2

ETS1.C: Optimizing the Design Solution

MS-ETS1-3

MS-ETS1-1

MS-ETS1-4

Common Core State Standards:

CCSS.MATH.CONTENT.6.SP.B.5.A

CCSS.MATH.CONTENT.7.SP.B.4

CCSS.MATH.CONTENT.HSS.ID.A.4

CCSS.MATH.CONTENT.6.SP.A.2

CCSS.MATH.CONTENT.7.SP.C.8

CCSS.MATH.CONTENT.HSS.IC.B.6

CCSS.MATH.CONTENT.6.SP.B.5.C

CCSS.MATH.CONTENT.HSS.ID.A.2

RST.11-12.8

CCSS.MATH.CONTENT.7.SP.A.2

CCSS.MATH.CONTENT.HSS.ID.A.3

RST.6-8.7

RST.6-8.9

ISTE Standard(s):

7.GLOBALCOLLABORATOR.C

4.INNOVATIVEDESIGNER.C

Materials:

- Foam Board (1/2" thick)
- Push Pins (Sphere shape)
- Marbles (large and small)
- Pencil
- Ruler
- Sharpie
- X-Acto knife

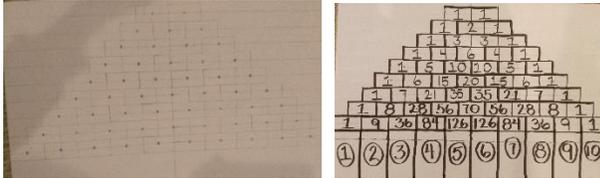
Preparation:

- This lesson is an example of how students can build a Galton Board. To challenge students, allow them to plan their Galton Board and the materials they will need. There are further links provided that show other ways Galton Boards have been created. If you have a woodworking shop, use wood or if you have a 3D printer, use the printer.
- Pascal's Marble Run by Karl Sims: <http://www.karlsims.com/marbles/index.html>
- Galton Board Made with Legos: <https://www.youtube.com/watch?v=aGiKdJ2npc4>
- Physlab: <http://physlab.org/class-demo/galton-board/>
- Quincunx Board: <http://mathematicsprojects.blogspot.com/2007/06/quincunx-board.html>

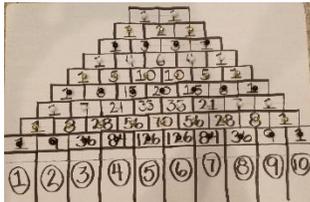
Lesson:

- If students have not been introduced to the Engineering Design Process, use this Youtube video The Engineering Design Process: A Taco Party: https://www.youtube.com/watch?v=MAhpfFt_mWM
- Pass out The Engineering Design Process sheet.
 - o Discuss the steps of the process and students can share examples of each step. You can use the Taco Party idea to help students.
 - o **Define:** How can we develop a Galton Board to analyze numbers and probability?
 - o **Brainstorm:** How can your group develop a Galton Board?
 - o **Select:** What type of project will best create a Galton Board and help the group to obtain and analyze data?
 - o **Identify:** What materials, jobs of groups member will you need for the project?
 - o **Create:** Groups create their Galton Board.
 - o **Test:** Groups test their Galton Board. Can they obtain and analyze data? Are they able to find the mean and create a bell curve (from the data)?
 - o **Improve:** Were students able to develop a proper Galton Board, collect, and analyze data? If not, were in this project can it become improved?
 - o **Share:** Students present their Galton Board, their process of developing their Galton Board, and findings to their classmates.
- Students move into their groups to begin discussions on developing their Galton Board.
- You can break down this lesson into days (**example below**):
 - o Day 1: Define, Identify, Brainstorm, and Select
 - Students may need a couple of days to obtain materials
 - Students draw their selected solution and identifying the materials needed to create the solution.
 - **Example:** Students decide to use Foam board, push pins, and marbles to develop a Galton Board.
 - o Day 2: Develop a prototype
 - Middle School: Does the Galton Board properly move beads from the top to the bottom? Are students able to find the mean, develop a bell curve, and locate the symmetry.
 - High School: Does the Galton Board properly move beads from the top to the bottom? Are students able to find the total area, standard normal distribution, and symmetry?

- Day 3: Develop a prototype
 - In the prototype, students can also draw out Pascal's Triangle onto their project.
 - **Example:** Students measure out equal squares (to create the Triangles) and make a circle of where the push pin will be placed.
 - **Example:** Students create a box, or use a shoe box, and place their Pascal Triangle in the box. This will collect the marbles that students drop to move through the Galton Board.



- Day 4: Test the prototype
 - Example: Students test their Galton Board by placing the main board into the collect box and drop large or small marbles one by one.
 - To collect data, one student will drop the marbles, one student will write down what number column the marble dropped into.
 - Once data is collected, students should be able to find the mean and develop a bell curve.



- Day 5: Improve the prototype
- Day 6: Share your solution with the class.
- When students have engineered their projects, they share with the class how they developed their Galton Board and show the Galton Board in use.

Check for Understanding:

- Students develop a Galton Board using the Engineering Design Process
- In their presentations, students share how they used the Engineering Design Process and what worked and didn't work for their Galton Board.
- The Galton Board, students developed, helped them to collect and analyze data. Middle school students were able to use the data to find the mean, create a bell curve, and find the symmetry. High school students were able to use the data to find standard normal distribution and symmetry.