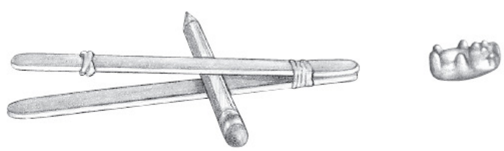
Designing an Experiment, Part 1 – Bears in Space

This activity consists of two **treatments**: one book (flat ramp) and three books (steep ramp). The **response variable** is the launch distance. Pay close attention to the variation in launch distances within each of these treatments.

GETTING READY

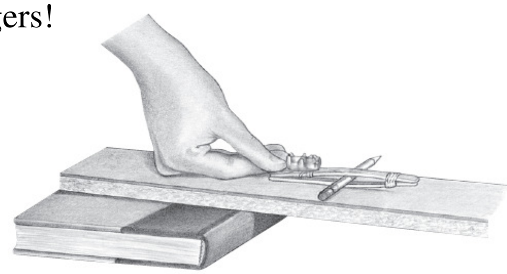
1. **Randomize.** Your team will be told which of the two treatments you will have – the one book or the three books. The same number of teams will be assigned to each treatment.

2. **Construct your launcher.** Make your launcher from tongue depressor sticks and rubber bands. First, wind a rubber band enough times around one end of a stick so that it stays firmly in place. Then, place that stick and another together and wind a second rubber band tightly around the other end of the two sticks to bind them firmly together. Insert a pencil between the two sticks as a fulcrum.

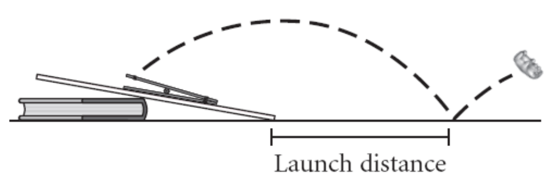


How to build a bear launcher.

3. **Organize your team.** Decide who will do which jobs: Hold the launcher on the ramp, load the gummy bear, take measurements, and record the data. When you launch, use a coin instead of your fingers…or you could end up with very sore fingers!



Setting up the launch.



Measuring the launch distance.

GATHERING DATA

4. **Your team will perform ten launches.** After each launch, record the distance, in centimeters. Measure the distance from the ***front*** of the ramp, and measure only in the direction ***parallel*** to the ramp.

Launch	1	2	3	4	5	6	7	8	9	10
Distance										

5. **Record the data.** From the Global drive, under my name, open your class period's folder, and open the Fathom document ***Bears in Space***. Use the first case table that looks like this to enter your distances:

	Launch	Team	Books	Distance
units				centimet...
1	1	4	1	87 cm
2	2	4	1	101 cm
3	3	4	1	96 cm

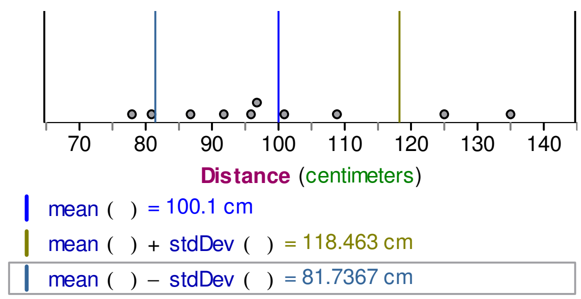
INVESTIGATE

Within-Team Variability

6. **Make a dot plot of your team's ten launch distances**. Place the Distance on the x-axis.

7. **To summarize the center and spread, calculate the mean, median, and standard deviation in a summary table.** Drag a blank summary table from the shelf. Drag *Distance* to either arrow in the summary table. The mean will automatically be calculated. To get the standard deviation, choose **Summary , Add Basic Statistics**. To get the median, choose **Summary , Add Five-Number Summary**.

8. **Plot the center and spread on your graph**. Select the graph, choose **Graph , Plot Value**, and enter **mean( )**. Do the same to plot **mean( )+stdDev( )** and **mean( )-stdDev( )**.



Q1. Why do the launch distances vary so much for your team? List as many explanations as you can, then order them, starting with the one you think has the most effect, and on down.

Q2. One important source of variability between launches is the effect of practice! Can you think of an alternative strategy that would reduce (or come close to eliminating) the variability due to practice?

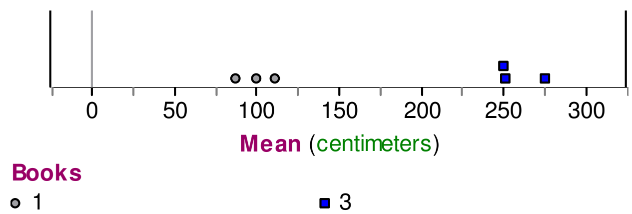
Q3. Use your answers to write an *experimental protocol*, a set of rules and steps to follow to keep launch conditions as nearly-constant as possible. Your protocol should include rules for deciding when – if ever – not to count a "bad" launch.

Between-Team Variability

9. **The teacher will record each team's summary statistics** (mean, SD, median) and post them on the board. Enter every team's summary measures into the case table that looks like this:

	Team	Books	Mean	SD	Median
units			centimet...	centimet...	centimet...
1	1	1	99.7 cm	17.9 cm	105.9 cm
2	2	3	251.4 cm	26.8 cm	268.1 cm
3	3	3	249.9 cm	21.0 cm	240.9 cm

10. **Make a dot plot** with two kinds of dots – one for each launch angle. To do this, choose one of the summary measures (mean, SD, or median) and drop it on the x-axis. Then drag *Books* and drop it in the interior of the graph **while holding down the Shift key**.



Q4. Which measure of center (mean or median) gives a better summary of your team's set of ten launches? Or are they about equal? Give reasons for your judgment. (To form an opinion on this question, you may want to repeat step 10 for both mean *and* median and compare the dot plots.)

11. **Make a summary table.** Drag *SD* to one arrow and *Books* to the other arrow. Hold down the Shift key while you drop *Books*. Double-click the formula for **count( )** and delete it. What you are looking at now is the average standard deviation for the teams that had one book at the teams that had three books.

Q5. Is there more variation between your own team's ten launch distances (from step 7) or between all the teams that had the same number of books as you? Where does the average standard deviation for the teams with the other number of books fit in? Why do you think the team summaries vary as much as they do? List as many explanations as you can.

Q6. What strategies would you recommend for managing the variability between the teams that had the same launch angle?

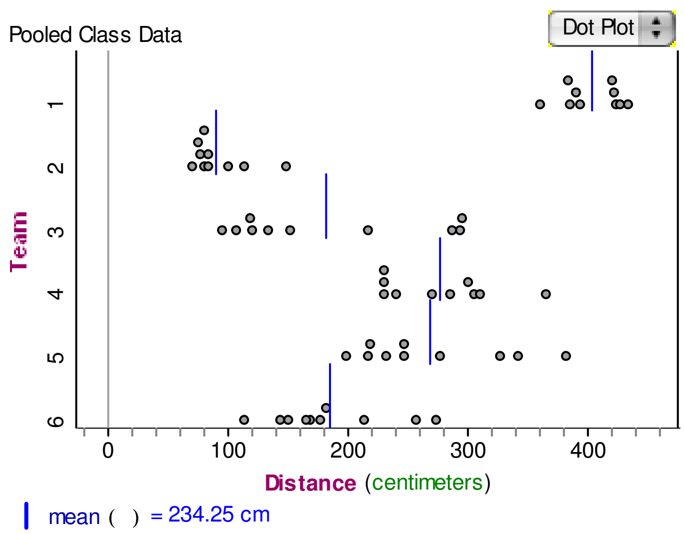
Between-Treatment Variability

Now you'll use the data from the entire class to think about ways to use the data to measure and compare the sizes of the three kinds of variability:

- within-team variability
- between-team variability
- between-treatment variability

12. **WHEN YOU ARE TOLD IT IS OKAY TO DO SO,** open the Fathom document ***Pooled Bears***. This document has each team's results.

13. **Make the dot plot and summary table shown**, using the entire class data from this "pooled" document. Hold down the Shift key while dropping *Team* and *Books*. On the dot plot, do a **Plot Value** for either measure of center (mean or median). On the summary table, double-click on the **count( )** formula and replace it with the same measure of center that you plotted on the display.



Pooled Class Data

		Books: 1	Books: 3	Row Summary
Team	1	403.3 cm		403.3 cm
	2		91.2 cm	91.2 cm
	3		181.7 cm	181.7 cm
	4	276.5 cm		276.5 cm
	5	268.3 cm		268.3 cm
	6		184.5 cm	184.5 cm
Column Summary		316.033 cm	152.467 cm	234.25 cm

S1 = mean (distance)

Q7. Can you say which kind of variability is the largest? The smallest? Explain.

Q8. Without doing a formal analysis, choose a tentative conclusion from this set of three choices, and give your reasoning.

I. Launch angle clearly makes a big difference.

II. Launch angle may very well make a difference, but there's too much variability from other sources to be able to isolate and measure any effect due to launch angle.

III. There's not much variability anywhere in the data, so it's safe to conclude that the effect due to launch angle, if there is any, is quite small.