OVERVIEW

In this activity, students analyze data collected from dropping two pieces of paper, one heavy and one light, onto a target and recording how far they land from the target. Students first establish common procedures and then collect data. Once collected, group data are entered into TinkerPlots and students analyze their group's results, as well as their overall performance compared with that of other groups.

Students learn to make a variety of plots that may be new to them (such as a time-series plot and a connected line plot). If students are unfamiliar with the basic technique of making a plot by fully separating and stacking data values, you'll need to show this. (See the movie "TinkerPlots Basics.") You may also need to help them with plotting averages and hat plots in Steps 17 and 18.

Activity Time: Two to three class periods

Objectives

- Understand the importance of using consistent procedures when collecting data.
- Compare data for two types of paper and determine which produces better results.
- Learn that different data displays make some things easier to see and some things harder to see.
- Compare several samples and determine which sample contained the most accurate (least variable) results.

Common Core Standards Addressed

Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions.

Grade 7, Statistics and Probability Standard 2

Use measures of center and measures of variability for numerical data from random samples to draw informal comparative inferences about two populations.

Grade 7, Statistics and Probability Standard 4

Prerequisites

- A basic introduction to using TinkerPlots
- Experience using measures of center to compare two groups

Materials

- Paper Drop worksheet
- **Paper Drop.tp**
- **Paper Drop Simulation.tp**
- Paper Drop Data Table (one per group, a blackline master is supplied at the end of these Notes)

- Lightweight paper
- Heavyweight paper
- Pennies or other coins (one per group)
- Poster paper for making graphs
- Rulers
- Tape (for hanging graphs on the wall)
- Colored pens

Credit

This activity is adapted with permission from the activity "Orbital Express," *Data in Depth: Exploring Mathematics with Fathom,* by Tim Erickson, Key Curriculum Press, 2001.

Lesson Plan

Introduction (15 minutes)

In this activity, students explore whether a light piece of paper or a heavy piece of paper lands closer to a target (a coin) when dropped. Introduce students to their task, and demonstrate how this might be done. Then ask students which type of paper they think will land closer to the target.

Divide your class into groups of three or four. Have each group collect the required materials and attempt the experiment three or four times to get a feel for what will happen. Then bring the class back together to discuss their hypotheses and establish common procedures.

Explain to students that because they will be comparing their group's data to that of other groups, it is important for each group to use the same procedure. You might ask them to come up with some things that might vary from group to group, before adding some of your own. Here are some suggestions for possible common procedures:

- Drop the paper from eye height.
- Measure the distance the paper landed from the target by measuring from the center of the coin to the nearest paper edge, in centimeters. Make sure the whole class uses the same units, so students can easily compare their data to that of other groups.
- Alternate dropping a heavy paper and a light paper throughout the experiment.

These suggestions are based on observations of common differences in how groups will begin to collect data. The class may choose different guidelines, as long as they all follow the same set. Write the guidelines on the board, so groups can refer to them throughout the experiment.

Data Collection (15 minutes)

Hand out one copy of the Paper Drop Data Table to each group. Have students work in their groups to collect data and record the results, dropping each type of paper 15 times. Point out that they should record their data in order, as order may influence their results.

Data Representation (25 minutes)

Once groups have collected their data, they will each make a plot on poster paper that helps show whether one type of paper tended to land closer to the target. They'll also write a short

statement describing which type of paper lands closer to the target, using their data to support their assertion. Post the posters around the room so students can see what other groups came up with. You might take a few minutes to quickly point out or discuss some of the more prominent differences in plots and results.

Student Work at Computers (20 minutes)

Once students have written their statements and drawn their plots, have them go to a computer and open **Paper Drop.tp**. Then have them work individually or in pairs to record their group's results in the case table, and answer the questions in Steps 13–18 on the worksheet. In Step 9, they'll save their documents with titles that include the group name and their own name, for example, **Paper Drop The Best RyanR.tp.** You may wish to have students e-mail you the document or save it to a place you can access, to facilitate combining the data from the entire class.

Once you have collected the data from each group, open **Paper Drop.tp** and enter the data from every group into one case table. To do this quickly, open one group's document and click the case table. Go to the **Edit** menu and choose **Select All Cases,** then return to the **Edit** menu and choose **Copy Cases.** Return to the document **Paper Drop.tp,** click the case table, and choose **Paste Cases** from the **Edit** menu. This adds the group's data to the case table. Repeat this process until you have copied the data from every group into one document. Resave this document as **Paper Drop Class Data.tp.**

Inspect the document for errors. For example, a group may not have used the exact group name every time. Or groups may have entered a space within their distance, causing it to be a qualitative attribute. You can see this by looking at the attribute's color bar. If it is a gradient, then all its values are numbers; if it consists of multiple distinct colors, then it has at least one non-numeric character. You can often spot this by looking at the column in the case table, or by making a plot. Once you have confirmed that there are no errors in the data, distribute the document to the class.

Wrap-Up (25 minutes).

Have students look at the combined data in TinkerPlots and finish the worksheet individually, in groups, or as a whole class.

It may help to allow groups to ask questions of one another, to determine if there were inconsistencies in how they collected data and to help understand why they decided to represent their data in a certain way. You may wish to ask students some of these questions:

What benefits do you see in each of the different displays groups came up with?

Which displays do you think will be easiest for people who didn't do this activity to understand?

You may also wish to discuss as a class the different methods students used for measuring consistency.

ANSWERS

1. Students will suggest several theories about why one type of paper might behave differently from another. The particular answers are not important. What is helpful is to make sure your expectations are explicit before collecting data. It increases the level of surprise when things turn out differently than we expect.

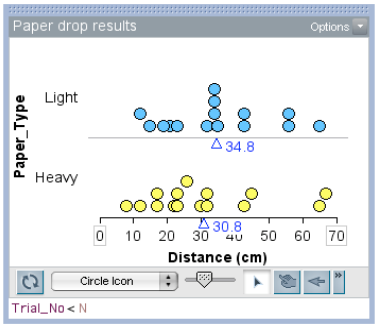
5. Answers will vary. Students should support their claims with data, and those claims should be consistent with their data.

13. Students may notice their results improving over time, or that drops that land close to the target are followed by drops that land far from the target.

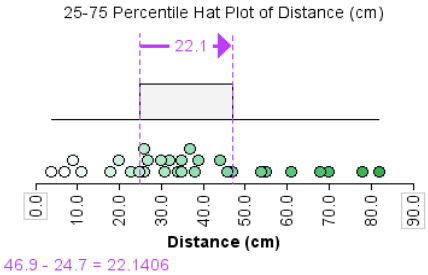
15. Data from different groups will likely show different trends. Students may have difficulty seeing general trends and instead focus on local changes. Encourage these students to look at the bigger picture by prompting them with questions such as "Overall, were your results getting better or worse over the 30 trials?"

16. Students may suggest that the dropper gets overly confident after a good drop and therefore does a poor job on the next drop, and perhaps after a poor drop the dropper tries harder. Alternating paper types contributes to this effect, as one type of paper may tend to land closer than the other. However, even if you look at the results of one type of paper, you will see a well-known effect called *regression toward the mean*. If students have a very bad trial, chances are that the next trial will not be as bad simply because the bad one was such an extreme. Similarly, if they happen to hit the target on one drop, the next trial will probably not be as good. Regression toward the mean is all around us. If a player has a great game, chances are that her next game will not be as good; and a poor performance will likely be followed by a better one.

17. Answers will vary. Students might make a plot with *Distance* on the horizontal axis, and *PaperType* on the vertical axis. Students might use dividers to show center clumps, mark the mode if there is one, or click the **Mean** or **Median** button to show averages.



18. Answers will depend on your students' prior experience with measures of variability and how much time you give them for this activity. If students have little experience with measures of variability, many will use the range or the thickness of the center clump. Students with more experience might use the distance measured along the crown of the percentile hat plot (shown here). With even more experience and given more time, students might experiment with the **Measure All** capability of the **Ruler** tool to create their own measure of average distance from the mean or median (for example, the absolute average deviation).



20. Groups whose *Distance* values were closest to zero will probably be considered best, but be open to other reasonable assertions.

21. Possible explanations include differences in ability, height differences (if people drop from eye level, then taller people are dropping a longer distance), chance (maybe someone had just one or two bad drops), and practice (some groups may have practiced more before they started).

22. Answers will vary. A group with *Distance* values all very close to each other may be considered very consistent, even if their *Distance* values are not close to zero.

23. This is another way of asking the question posed in Step 18, but students may now be able to consider alternatives, as they are now looking at data from several groups that are clearly different from one another. You might suggest that students use the measures of variability they developed in answering Step 18. Comparing different measures of variability will likely spark a discussion about why certain measures are better than others. For example, one bad drop can influence the value of the range for a group whose performance otherwise might be very consistent.

24. Time-series graphs will be useful in answering this question. Groups with distances that got closer to zero will have shown improvement.

25. Students should make a plot that shows *Distance* on one axis and *Paper_Type* on the other. They can use this plot to compare the locations of the centers (averages, middle clumps) of the two groups.

Paper Drop Data Table

Team Name: _____
Team Members: _____
_____
_____
_____

Trial #	Paper Type	Distance
1	Heavy	
2	Light	
3	Heavy	
4	Light	
5	Heavy	
6	Light	
7	Heavy	
8	Light	
9	Heavy	
10	Light	
11	Heavy	
12	Light	
13	Heavy	
14	Light	
15	Heavy	
16	Light	
17	Heavy	
18	Light	
19	Heavy	
20	Light	
21	Heavy	
22	Light	
23	Heavy	
24	Light	
25	Heavy	
26	Light	
27	Heavy	
28	Light	
29	Heavy	
30	Light	