Don't Spill the Beans!

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Overview of Lesson
Which hand can hold more beans, your dominant hand, or your non-dominant hand? This activity will introduce students to making hypotheses, and then designing an experiment to test their hypothesis. Principles of a good experimental design, including randomization of which hand is used first, will be emphasized. Students will collect and record their data, use graphical methods to describe their data, and finally analyze and interpret their results in the context of the activity.

GAISE Components
This investigation follows the four components of statistical problem solving put forth in the *Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report*. The four components are: formulate a question, design and implement a plan to collect data, analyze the data by measures and graphs, and interpret the results in the context of the original question. This is a GAISE Level B activity.

Common Core State Standards for Mathematical Practice
1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.

Common Core State Standards Grade Level Content (Grades 7 and 8)
7. SP. Draw informal comparative inferences about two populations.

NCTM Principles and Standards for School Mathematics
Data Analysis and Probability Standards for Grades 6-8

Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them:

- formulate questions, design studies, and collect data about a characteristic shared by two populations or different characteristics within one population;
- select, create, and use appropriate graphical representations of data, including histograms, box plots, and scatterplots.

Select and use appropriate statistical methods to analyze data:

- discuss and understand the correspondence between data sets and their graphical representations, especially histograms, stem-and-leaf plots, box plots, and scatterplots;

- find, use, and interpret measures of center and spread, including mean and interquartile range.

Develop and evaluate inferences and predictions that are based on data:

- use observations about differences between two or more samples to make conjectures about the populations from which the samples were taken.

Prerequisites

Students will have knowledge of making measurements using a stopwatch and measuring the volume of beans collected. Students will have knowledge of how to organize data in a table. Students will have knowledge of how to create boxplots. Students will have knowledge of how to interpret descriptive statistics.

Learning Targets

Students will be able to understand how to collect and interpret statistical information. They will also learn how to create and implement a statistical investigation. In addition, students will be able to analyze and interpret the data.

Time Required

Approximately one 45-50 minute class period; some discussion time the following class period might be necessary.

Materials Required

Graphing calculator or computer with spreadsheet or statistical software that can be used to create and print boxplots, a large container of dried beans, a large measuring cup with milliliters, a coin, and a stopwatch.

Instructional Lesson Plan

The GAISE Statistical Problem-Solving Procedure

I. Formulate Question(s)

Begin by asking the students to make hypotheses about which hand (dominant or non-dominant) can hold more beans.

Ask students to write some questions that they would be interested in investigating about students' hand capacity. Some possible questions might be:

1. Why is the question formulated in terms of dominant and non-dominant hand, rather than left or right hand?
2. Are the dominant and non-dominant hands the same size, or is one hand larger than another?
3. Do males and females display the same relationship between hand sizes, or might male and female hand sizes differ somehow?

II. Design and Implement a Plan to Collect the Data

Guide students in setting up an experiment to test their hypothesis. Decide as a class the procedures for the experiment. Emphasize that they are not competing with each other, but comparing each student's two hands. Consider, for example, hand position, distances to

transport the beans, etc. Also consider which hand should be tested first. Should everyone use their dominant hand first? Why? Or why not? Discuss the idea of determining a random order for which hand to use first for each student. Additionally, discuss why not using a random order could affect the overall results. Discuss ways to determine a random order. One possibility is to have each student flip a coin to decide which hand should be used first. Appoint one person to be the timer. When the timer starts the stopwatch, a student takes fistfuls of beans and puts them into another container. After three seconds, the student stops and measures the volume of beans he or she was able to transfer (in millileters). Results are recorded for which hand was used and whether it was the dominant or non-dominant hand.

III. Analyze the Data

Sample class data values are presented below. A data collection table is provided on the Activity Worksheet on page 7.

Table 1. Sample class data.

Student	Dominant Hand	Non-Dominant Hand	Difference
Todd	230	205	25
Jordan	166	136	30
Erin	179	118	61
Jessica	150	150	0
Matt	179	193	-14
Bethany	234	170	64
McKensie	172	141	31
Brandon	142	122	20
Stephanie	152	142	10
Ashley	154	123	31
Kendra	204	206	-2
Sam	179	136	43
Lisa	212	200	12

Have students use appropriate technology (graphing calculator, Excel, statistical software) to create parallel boxplots of the volume of beans collected by the dominant and non-dominant hands. Parallel boxplots for the sample class data are shown below.

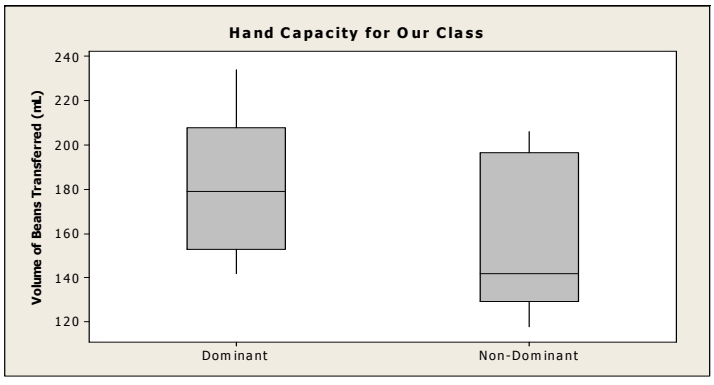

Figure 1. Parallel boxplots for volume of beans transferred.

Discuss with students how to interpret the parallel boxplots. Students should understand that there are about the same number of volume values between the minimum and Quartile 1, Quartile 1 to Quartile 2, Quartile 2 to Quartile 3, and from Quartile 3 to the maximum.

Ask students to describe similarities and differences in the bean volume distributions. Overall the dominant hand appears to be able to hold and transfer more beans than the non-dominant hand. The median bean volume for the dominant hand is at about 180 mL versus the median bean volume for the non-dominant hand, which is close to 140 mL. The first quartile for the dominant hand (about 155 mL) is higher than the median for the non-dominant hand. About 75% of the bean volumes for the dominant hand are at or above 155 mL. Less than 50% of the bean volumes for the non-dominant hand are at or above 155 mL. The bean volume values show more variability in the central 50% of the distribution for the non-dominant hand (as seen by the box length, or interquartile range). The overall variability for the bean volumes is comparable for the two hands (as seen by the range).

The parallel boxplots seem to indicate that the dominant hand is able to hold and transfer a higher volume of beans than the non-dominant hand.

To start the rest of the lesson ask students to calculate the change (difference) in the bean volume for each student (defined as dominant hand bean volume minus non-dominant hand bean volume). Ask students to think about what positive and negative differences imply. What does a positive difference indicate? What does a negative difference indicate?

Have students construct a boxplot of the differences. The boxplot for the differences for the sample class data is shown in Figure 2.

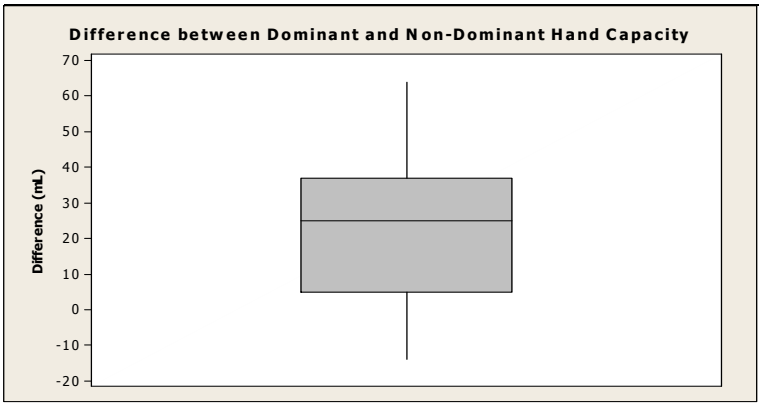

Figure 2. Boxplot for difference in volume of beans transferred.

Ask students: If the dominant hand is able to hold and transfer a larger volume of beans, what features should we see in the difference data distribution? Students should note that if the dominant hand can hold more beans we would expect to see a large percentage of positive differences. Does the boxplot provide evidence in either direction regarding which hand can hold more beans? Did most students hold more beans with their dominant hand or their non-

dominant hand? What aspects of the boxplot can be used to justify your answer? The boxplot of the bean volume differences clearly illustrates that the dominant hand tends to be able to hold and move more beans than the non-dominant hand. This can be seen by noting that Quartile 1for the difference distribution is above zero. So at least 75% of the students were able to hold and transfer a greater volume of beans with their dominant hand.

Ask students: In what ways is the boxplot for the difference in bean volume more informative than the parallel boxplots constructed earlier for the bean volumes for the dominant and non-dominant hands? When examining the parallel boxplots constructed earlier, even though the dominant hand appears to have a higher volume of beans, there is clearly some overlap in the bean volume values for the two hands. The difference boxplot more clearly shows that the dominant hand is able to hold more beans.

IV. Interpret the Results

Ask students to summarize the results of their data analysis and the class discussion by answering questions, such as:

1. What information is provided by the boxplots?
2. Which plot (parallel boxplots or single boxplot of the differences) makes it easier to draw a conclusion about how many beans can be held by the dominant and non-dominant hands?
3. How can each plot be used to answer the research question?
4. Do the boxplots provide evidence in support of our hypothesis?
5. How is this evidence seen in the boxplots?
6. What surprised you about the results?

Assessment

1. Can we conclude that dominant hands are always larger than non-dominant hands?

2. Can we claim that the boxplots represent the relationship between dominant and non-dominant hands in the general population? Why or why not?

3. Do we have sufficient information to ask whether male and female students show the same type of relationship between dominant and non-dominant hand volumes?

4. Why are you randomly determining (using a coin) which hand to start with?

Answers

1. No, we cannot. In our sample data, there are two students whose dominant hand transferred less than the non-dominant hand.
2. No, we cannot claim that the boxplots represent the relationship between dominant and non-dominant hands in the general population. These data values were collected for students; there is no guarantee that as adults or younger children this same relationship between dominant and non-dominant hands holds true.
3. We probably do not have enough data to draw a conclusion regarding gender differences. If we collect more data, being sure that we have both male and female students represented, we might be able to draw such a conclusion.
4. Randomization of hand allows us to eliminate the effect of always starting with the dominant (or non-dominant) hand. Through randomization of starting hand, we can rule out the possibility that the first hand used (or the second hand used) grabs more or fewer beans simply due to being the first time the subject might have done this activity.

Possible Extensions

1. Students can be asked to calculate descriptive statistics for the bean volume values for the two hands. Measures such as the mean, standard deviation, the median, and quartiles can be calculated and interpreted. Measures can be compared for the two hands. Students can be asked to check for outlying data values.
2. Students can be asked to calculate descriptive statistics for the differences in bean volume values (dominant hand minus non-dominant hand).
3. The amount of time allotted to transfer the beans could be increased and difference results could be compared with the allotted time of 3 seconds.

References

Adapted from an activity created by Paul J. Fields, Ph.D. for the *American Statistical Association Meeting Within a Meeting Program for Middle School Teachers* (2008).

Don't Spill the Beans! Activity Sheet

Which hand can hold more beans, your dominant hand, or your non-dominant hand? This activity will introduce you to making hypotheses, and then designing an experiment to test your hypothesis.

1. Why is the question formulated in terms of dominant and non-dominant hand, rather than left or right hand?

2. Describe the data collection process you will use to answer the research question.

3. Working in groups, each student should flip a coin to decide which hand should be used first. Appoint one person to be the timer. When the timer starts the stopwatch, a student takes fistfuls of beans and puts them into another container. After three seconds, the student stops and measures the volume of beans he or she was able to transfer, in milliliters (mL). Record the volume of beans transferred, and whether it was the dominant or non-dominant hand. Combine all the data collected by the students in the class into one table.

Data Collection Table

Student Name	Dominant Hand (mL)	Non-Dominant Hand (mL)	Difference (mL)

4. Using appropriate statistical software, make parallel boxplots of the volume of beans transferred using dominant and non-dominant hands, as well as a boxplot of the differences in volume between the dominant and non-dominant hand. If you cannot print your boxplots, make sketches of them in the space below.

5. Does there appear to be support for your research question? Carefully explain the reasoning behind your answer.

6. Which plot (the parallel boxplots or the single boxplot of differences) seems to be more useful in answering your research question? Does one of the plots provide stronger evidence to support or refute your research question?