Teacher Guide: Real-Time Histogram

Learning Objectives

Students will …

- Measure their ability to estimate a 2-second time interval.
- Compare the results of time-estimation tests with and without feedback.
- Find the mean and range of a data set.
- Calculate error and percent error.
- Analyze data using a histogram and scatter plot.
- Calculate the standard deviation of a small data set.
- Understand how standard deviation is related to the distribution of data.
- Design and carry out a time-estimation experiment. (Extension)

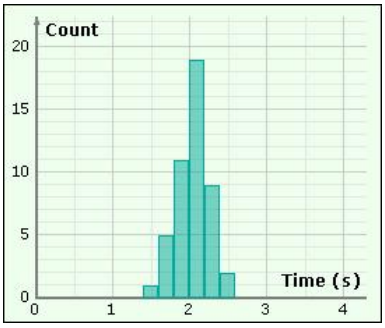
Vocabulary

absolute value, error, histogram, mean, normal distribution, percent error, pulse, range, standard deviation

Lesson Overview

Without using a watch, how could you estimate how long a second lasts? Galileo famously used his pulse to measure time in his acceleration experiments. Kids playing touch-football have to count (one-Mississippi, two-Mississippi, etc.) up to five before they can charge the quarterback.

The *Real-Time Histogram* Gizmo™ allows students to test their own ability to estimate a 2-second interval. Time-estimation data can be shown on a scatter plot or on a histogram. Students can compare data sets using a variety of statistics such as mean percent error and standard deviation.



How well can you estimate a 2-second interval?

The Student Exploration sheet contains two activities and an extension:

- Activity A – Students use basic statistics (mean, range, error, and percent error) to compare time estimation with and without feedback.
- Activity B – Students explore standard deviation.
- Extension – Students design and execute a time-estimation experiment.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Pulse rate** (5 minutes)
   Have students find their pulse on their wrist or neck. To find their wrist pulse, students can hold their hands perpendicular to their desk (like a “karate chop”). The pulse can be found on the inside of the wrist, below the thumb, about 1 inch (2.5 cm) from the base of the hand. Have students count the beats for 30 seconds and then multiply by two to find their resting heart rates. Discuss whether using their pulse would be a good way to measure short time intervals.

2. **Prior to using the Gizmo** (10 – 15 minutes)
Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

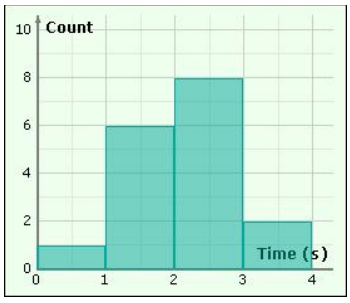
4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:
    - Which is the most useful measure of how well a person estimates a 2-second interval: mean time, range, mean error, or mean percent error? Why?
    - How does feedback affect time-estimation results?
        - How does a graph for an experiment with feedback differ from a graph for an experiment without feedback?
    - What does a large standard deviation indicate about a data set? What does a small standard deviation indicate?
    - Why can standard deviation be a more useful statistical measure than range?
    - What is the best method for estimating a 2-second time interval?
    - Why do many types of data tend to have a normal distribution?

5. **Follow-up activity: Standard deviation** (15 – 30 minutes)
One of the interesting things about the standard deviation is that it tells you how close data points are to the mean. If data follows a normal distribution, then 68% of the values will be within one standard deviation of the mean, 95% will be within two standard deviations of the mean, and 99% will be within three standard deviations of the mean.

    To demonstrate this, have each student collect a data set of 50–100 clicks. By turning on **Show statistics**, students can find the mean and standard deviation of the data set. Students can add and subtract the standard deviation from the mean, and then count how many values fall into this range. (This can be made easier by exporting the data into a spreadsheet and then sorting the values.) Students can then find how many values fall within two and three standard deviations of the mean as well.

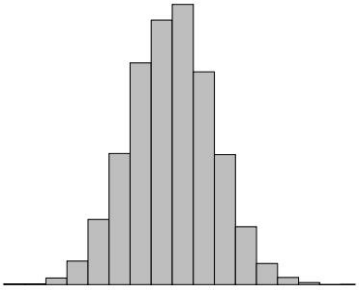
Scientific Background

The *Real-Time Histogram* provides a way for students to gather and analyze large amounts of data. An interesting way to view this data is on a *histogram*, a plot that shows how many values fall into equal categories, or "bins." For example, the simple histogram at right shows one point in the 0–1 second interval, six points in the 1–2 second interval, eight points in the 2–3 second interval, and two points in the 3–4 second interval.



Two useful statistics for assessing the accuracy of a measurement or estimation are *error* and *percent error*. The error is equal to the difference between the measured or estimated value and the actual value. The percent error can be found by dividing the error by the actual value and then multiplying this value by 100. Percent error is useful for comparing two measurements in which the actual values are very different.

Many types of data tend to have a *normal distribution*, also known as a *Gaussian distribution*. Data that has a normal distribution forms a bell-shaped curve when plotted on a histogram (right). The normal distribution is symmetrical and centered at the mean. In other words, the probability of a value exceeding the mean is equal to the probability of a value being less than the mean. Many biological data are normally distributed: the weight of all American males, the height of all Canadian females, the blood pressure of all Nebraskan 12-year-old females, etc. Time estimation data probably will follow a normal distribution as well.



Normal distribution

Data that has a normal distribution can be described by its mean (μ) and standard deviation (σ). The standard deviation describes how spread out the data is. If the data is tightly clustered around the mean, the standard deviation will be small. If the data is spread out, the standard deviation will be higher. The formula for standard deviation can be found in the Student Exploration of the *Real-Time Histogram* Gizmo.

Historical Connection: Galileo and time

Galileo Galilei had a lifelong fascination with time measurement. As a young medical student he observed a swinging chandelier in the Pisa Cathedral. Timing the swings with his pulse, he noticed how regular they were. Late in life, he made a plan for the first pendulum clock.

As Galileo carried out his famous experiments on acceleration and free fall, he needed an accurate way to measure short intervals of time. Galileo used a variety of methods for this, including his pulse, a swinging pendulum, and a water clock, which proved to be the most accurate method. The water clock consisted of a large water-filled vessel suspended over an empty vessel. The top vessel had a hole that Galileo could plug with his finger. Galileo would remove his finger when the ball started rolling down the ramp, and then replace his finger when the ball reached the bottom of the ramp. A measurement of relative time could be obtained by weighing the water that had drained into the second vessel.

Selected Web Resources

Standard deviation: http://www.robertniles.com/stats/stdev.shtml, http://davidmlane.com/hyperstat/A16252.html
Normal distribution: http://www.netmba.com/statistics/distribution/normal/
Galileo and time: http://galileo.rice.edu/sci/instruments/pendulum.html, http://www.daviddarling.info/encyclopedia/G/GalileoG.html

Related Gizmos:
Time Estimation: http://www.explorelearning.com/gizmo/id?50
Sight vs. Sound Reactions: http://www.explorelearning.com/gizmo/id?43
Reaction Time 1: http://www.explorelearning.com/gizmo/id?1028
Reaction Time 2: http://www.explorelearning.com/gizmo/id?1009