Eruptions: Old Faithful Geyser

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Purpose

Students analyze data and make predictions about eruptions of the geyser Old Faithful. They create a variety of graphical displays to discover trends in the data, and then they use those graphs to support their predictions. This task is appropriate for students familiar with line graphs and other graphical displays of univariate data sets.

Task Overview

Investigate wait times between successive eruptions (blasts) of the geyser known as Old Faithful by analyzing and representing data collected in Yellowstone National Park by the National Park Service and the U.S. Geological Survey. *An activity sheet that gives students the complete task (with a table of the data) is included.*

Focus on Reasoning and Sense Making

Reasoning Habits

Focus in High School Mathematics: Reasoning and Sense Making

Analyzing a problem—seeking patterns and relationships

Implementing a strategy—making purposeful use of procedures; monitoring one's progress, including reviewing a chosen strategy

Seeking and using connections across different representations

Reflecting on a solution—considering the reasonableness of a solution

Process Standards

Principles and Standards for School Mathematics

Problem solving—solve problems that arise in mathematics and in other contexts

Reasoning and proof—make and investigate mathematical conjectures

Representation—create and use representations to organize, record, and communicate mathematical ideas

Standards for Mathematical Practice

Common Core State Standards for Mathematics

1. Make sense of problems and persevere in solving them.
3. Construct viable arguments and critique the reasoning of others.
5. Use appropriate tools strategically.

Focus on Mathematical Content

Key Elements

Focus in High School Mathematics: Reasoning and Sense Making

Reasoning with probability and statistics—data analysis; interpreting designed statistical studies

Standards for Mathematical Content

Common Core State Standards for Mathematics

NS-ID-1. Represent data with plots on the real number line (dot plots, histograms, and box plots).

S-IC-1. Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

Materials and Technology

- Eruptions: Old Faithful Geyser activity sheet (includes a table of the data)
- Poster paper, if available, for graphs
- Computers or calculators with graphing capability, if available
- Random number generator (optional). An applet is available at www.MathRSM.net/applets/yellowstone, or you might use graphing calculators, playing cards, or other random selection methods

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Use in the Classroom

You might introduce the task by having students read or discuss information about Old Faithful, including the fact that the geyser continues to erupt regularly. Many online videos show Old Faithful erupting; showing such a video can provide support for students who are unfamiliar with the context.

When students experience a real-life context, even from a video, they can develop a stronger understanding of a problem set in that context and can have a better basis for reflecting on the reasonableness of their solutions.

Distribute the activity sheet and discuss the information that the table provides. The sheet directs each group of students to select two rows of data, giving them two sample days of Old Faithful wait times. You might prefer to assign rows to student groups by using a random number generator. See http://www.MathRSM.net/applets/yellowstone, or use another random selection method.

Students should then work individually on steps 1 and 2 on the activity sheet. They will need ample time to consider step 1, which asks them to examine their data and jot down "notices" or "wonders"—aspects of the data that they particularly notice or wonder about.

Students' "notices" and "wonders" can guide their thinking as they make sense of patterns and relationships in the data.

Students convene in their groups in step 3 to "share and compare" their work. Their conversations should address why each student selected a particular graphical display and whether that display provides a useful representation of the data. The students will then act as "data detectives" as they complete step 4, which calls on them to decide as a group on the length of time that they would expect to wait between blasts of Old Faithful.

Small groups can provide environments in which students can effectively discuss and evaluate the appropriateness of their graphical displays.

Students need to be able to articulate why they used a particular type of graphical display to represent the wait times. You might pose such questions as the following: "Which aspects of the data seem to support your prediction, and which aspects raise doubts?" "What does your graph tell you about the data?"

Evaluating how each graphical display informs, or fails to inform, students about the data and the context helps them learn how to use appropriate tools strategically.

It is important that students present their graphs and conclusions to the class. Encourage students to ask questions of one another, including questions that they pondered when analyzing their own blast data and that serve both to clarify and challenge what each group has presented.

Forming their own questions requires students to reflect on the reasonableness of the solutions being presented and to evaluate and critique the reasoning of others.

After the group presentations, you might ask the whole class to compare and contrast the different graphs created and used by all the groups. Possible prompts include the following: "What does each type of graph highlight for us?" "Do any of the graphs 'mask' some things in the data?"

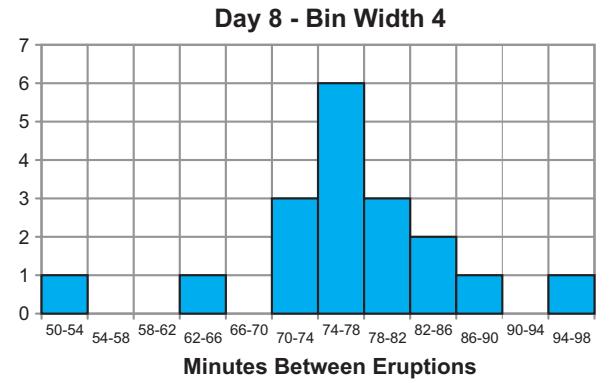
Teachers' prompts can help students consider the connections among different graphical representations of data.

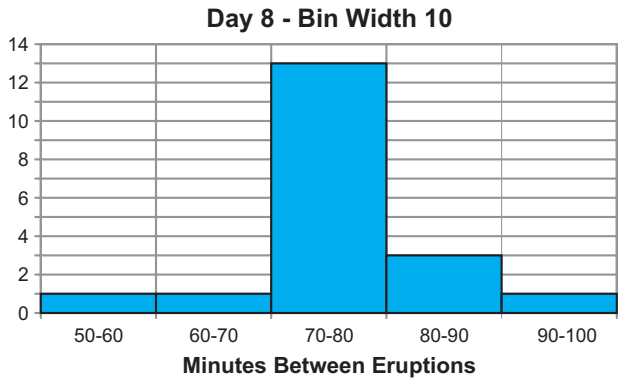
A discussion of the statistics that students use is important. If students use a measure of central tendency as their predicted wait time, you might ask them how confident they are about their predictions, probing their reasoning with questions such as, "What about the variability in blast times—does that bother you?"

Focus on Student Thinking

The types of graphs that students might create include (a) a bar graph or a line graph of wait times, ordered by blast number; (b) a stem-and-leaf plot; (c) a frequency graph; (d) a box plot; and (e) a graph over time.

Students might recognize that the frequency graphs can vary considerably, depending on the bin width selected. If students choose a bin width of 10 by default, you might ask, "How well does this bin width illustrate the shape of the data?" or, "Would a different bin width give you a better idea of the data?" For day 8, for example, a bin width of 4 reveals more about the shape of the data, as compared with a bin width of 10, as shown on next page.

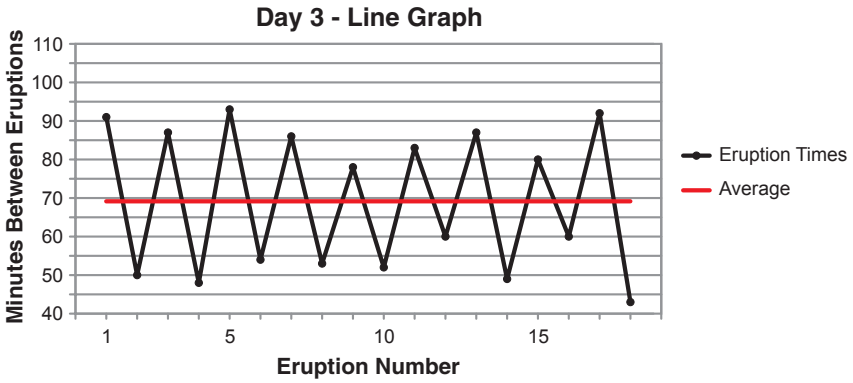


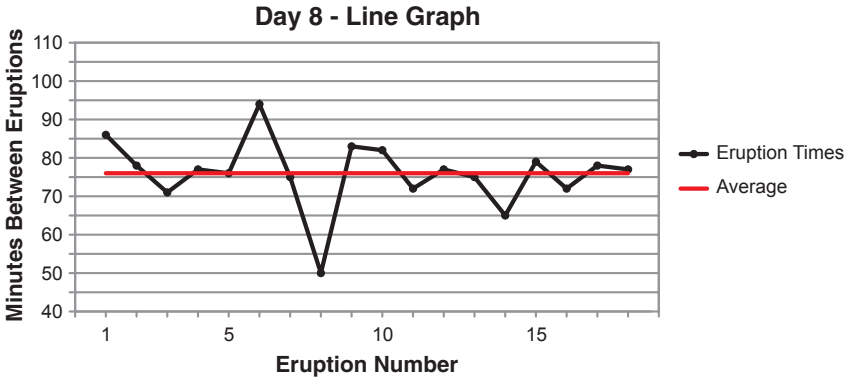


A graph over time or a line graph ordered by blast number might focus attention on the seemingly alternating behavior of "short" and "long" blasts (a long blast is usually followed by a short blast, and vice versa). This alternating behavior is not evident in frequency graphs, box plots, or stem-and-leaf plots. You might ask, "How would each type of graph change if the data were reordered?" This question could lead students to consider the types of conclusions that each graph can or cannot support.

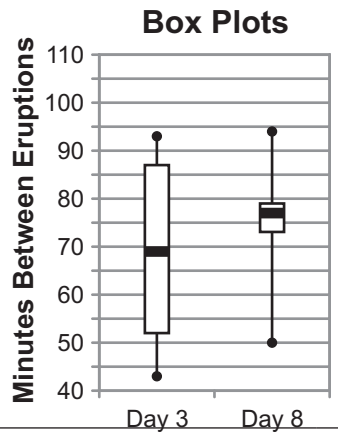
Some students might use a statistic such as the mean or the median to predict the wait time. They might note that these two measures can be quite different. Facilitate reflection on what this observation means, and probe for deeper understanding of these concepts. You might ask students, "What features in data will make the mean and median close together, and what features will make the mean and median far apart?" Asking students to create a small data set with those features can be instructional as students think about this question.

Students should also think about features in the data that might make the mean a useful predictor of the next blast time. On day 3, for example, the data alternate very regularly between long and short blasts, but on day 8, the alternating behavior is not evident. Ask students, "How could you visualize and quantify this phenomenon?" One approach would be to overlay the mean value on the line graphs for each day, as illustrated on the next page, and then observe how many data points are close to the mean value. On day 3, only three points are within 10 minutes of the mean; on day 8, fourteen points are within 10 minutes of the mean. Students might conclude that the mean is a better predictor of blast times for day 8 than it is for day 3.





Students who make box plots might also note the usefulness of the interquartile range in providing a measure of the variability of the expected wait time. Some teachers may consider that it is important for students to think about representations of variability. To help students do this, you might ask, "What features in the data will produce a narrow interquartile range, and how would those features be displayed in a line graph and box plot?" As shown below, box plots clearly display the wide difference in interquartile ranges for day 3 (34.5) and day 8 (6). Line graphs show wide deviations in the day 3 data from its average, with much smaller deviations in the day 8 data from its average.



Assessment

After the class discussion, you might ask each group to finalize a report of what the group did, or you might ask each student to complete an individual write-up. Consider the following sample prompt for such an exercise: "Write a letter to a friend who is going to visit Old Faithful. What would you tell your friend about how long to expect to wait for the geyser to blast, and why?"

Resources

National Council of Teachers of Mathematics (NCTM). *Principles and Standards for School Mathematics.* Reston, Va.: NCTM, 2000.

———. *Focus in High School Mathematics: Reasoning and Sense Making in Statistics and Probability.* Reston, Va.: NCTM, 2009. Chapter 2, "Eruptions of the Old Faithful Geyser—Becoming a Data Detective," pp. 25–41.

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGA Center and CCSSO). *Common Core State Standards for Mathematics. Common Core State Standards (College- and Career-Readiness Standards and K–12 Standards in English Language Arts and Math)*. Washington, D.C.: NGA Center and CCSSO, 2010. http://www.corestandards.org.

Eruptions: Old Faithful Geyser

Student Activity Sheet

The following table gives successive wait times, in minutes, between successive eruptions of the geyser known as Old Faithful. Each row represents approximately one day's worth of eruption times

Old Faithful Data																		
Day	**Minutes between Blasts**																	
1	86	71	57	80	75	77	60	86	77	56	81	50	89	54	90	73	60	83
2	65	82	84	54	85	58	79	57	88	68	76	78	74	85	75	65	76	58
3	91	50	87	48	93	54	86	53	78	52	83	60	87	49	80	60	92	43
4	89	60	84	69	74	71	108	50	77	57	80	61	82	48	81	73	62	79
5	54	80	73	81	62	81	71	79	81	74	59	81	66	87	53	80	50	87
6	51	82	58	81	49	92	50	88	62	93	56	89	51	79	58	82	52	88
7	52	78	69	75	77	53	80	55	87	53	85	61	93	54	76	80	81	59
8	86	78	71	77	76	94	75	50	83	82	72	77	75	65	79	72	78	77
9	79	75	78	64	80	49	88	54	85	51	96	50	80	78	81	72	75	78
10	87	69	55	83	49	82	57	84	57	84	73	78	57	79	57	90	62	87
11	78	52	98	48	78	79	65	84	50	83	60	80	50	88	50	84	74	76
12	65	89	49	88	51	78	85	65	75	77	69	92	68	87	61	81	55	93
13	53	84	70	73	93	50	87	77	74	72	82	74	80	49	91	53	86	49
14	79	89	87	76	59	80	89	45	93	72	71	54	79	74	65	78	57	87
15	72	84	47	84	57	87	68	86	75	73	53	82	93	77	54	96	48	89
16	63	84	76	62	83	50	85	78	78	81	78	76	74	81	66	84	48	93

These data were collected in Yellowstone National Park over a period of two weeks in 1985 by the National Park Service and the U.S. Geological Survey.

Pick any two rows of data so that your group has two sample days of Old Faithful wait times. (For best results, use a random number generator in the selection of your rows!)

Eruptions: Old Faithful Geyser

Student Activity Sheet—*Continued*

Working individually, take the following steps:

1. Look over the data. Is there anything that you notice, or anything that you wonder about, in your two samples of data? Jot down some of your "notices" and "wonders."

2. Create at least one type of graphical representation for each of the two days of data to help you visualize any patterns in the wait times. Jot down any additional notices and wonders that occur to you.

Next, working as a group, complete the following steps:

3. Share and compare. Share your graphical representation of the data in your group. What do you notice, or wonder about, as you look through your group's graphical representations?

4. Accept the challenge to act as "data detectives." Agree as a group on a graphical way to display your data. On the basis of your data, make a group decision about how long you would expect to wait between blasts of Old Faithful if you showed up at Yellowstone Park when Old Faithful had just finished erupting. Be prepared to present your graph to the other groups in your class and to defend your group's data-based prediction for the expected wait time.