HIDDEN FIGURES

There is a matrix of mathematics behind everything we see. Students can learn to find the numbers or quantify their observations to reveal and explore unseen patterns.

Time

Introduction: 10 minutes
Activity: 30–50 minutes
Discussion: 10 minutes

Materials

- ☐ Journals and pencils

optional

- ☐ Stopwatches or watches with second hands
- ☐ Measuring tapes/rulers (metric preferred)
- ☐ Protractors or goniometers
- ☐ Cut-and-Paste Quantification Tool Kit page

Teaching Notes

Many students have math anxiety. Help them reframe the fear. Numbers are just another language to describe the world. The goal at this introductory stage is to practice different approaches to quantification, not to follow a strict process in order to reproduce a calculation; do not penalize students for a wrong calculation in this context.

Stem-and-leaf plots and tally histograms (see p. 202) are great approaches for visualizing data. Teach students about these strategies in math class, so that they can apply them in the field in this activity and in other journaling experiences.

There are numbers behind our observations. Math is as beautiful as the world it describes. If you have an aversion to math, it is likely because you learned it outside of any meaningful context. If applied thoughtfully, mathematics is a simplified and symbolic language with which you can describe the world. On a plant, for example, the number of petals, its overall height, the distances between nodes, the number of visitations by pollinators, the number of aphids per leaf, and its speed of growth are all quantifiable measurements, and they all reveal something interesting about the plant. Teaching students to find the numbers behind their observations gives them a way to use math to reveal patterns they otherwise might not notice. They will be able to apply these skills in their future explorations and journal entries, adding another language and level of precision to the page.

Make a decision about how far to go with this activity. Introducing counting, measuring, timing, and estimating all at once might be too much for your group. If so, you might choose to focus on only one skill per outing. If your students are new to journaling, consider running this activity without journals, so that students only have to focus on one new skill at a time.

NATURAL PHENOMENA

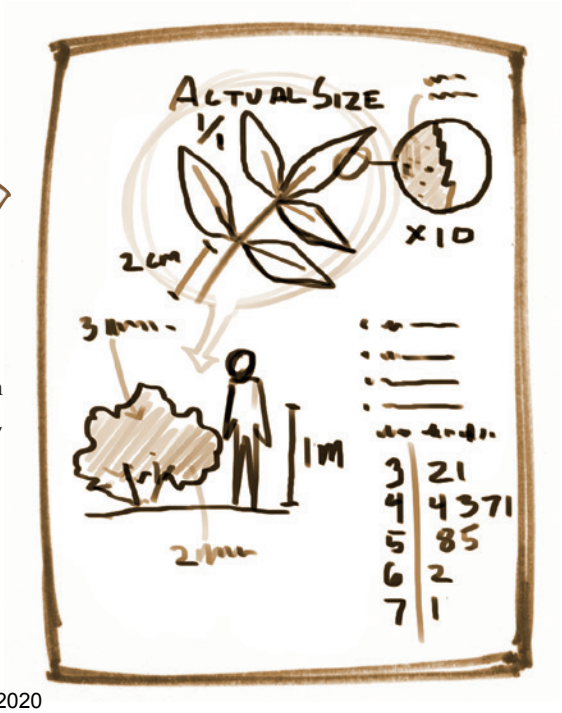
The goal of this activity is for students to practice quantifying parts of nature. Any event can be timed, any object can be measured, and there are things to count everywhere. Any area with different natural organisms and features will work.

PROCEDURE SUMMARY

1. Count [time, measure, or estimate] things around you, trying to find different ways to quantify your observations.
2. Be creative; there is no penalty for being wrong. Numbers are just another way to show observations.
3. Use your journal to record what you quantify.

DEMONSTRATION

When the whiteboard icon appears in the procedure description: Draw a sample journal page showing use of writing and drawing. Then add measurements, counts, scale, stem-and-leaf plots (if students are familiar with them), and other numbers.



PROCEDURE STEP-BY-STEP

1. **Explain that numbers, like words and pictures, are a way of describing observations; reference a nearby object in nature as an example.**
   - a. "We can show observations through words and drawings. We can also record observations through numbers."
   - b. "Look—over there, I'm noticing that there is a clump of gopher holes. I could say, 'There is a clump of gopher holes,' but I could also go count the number of gopher holes, or measure how wide each one is. This is a deeper level of observation."
2. **Tell students that they will practice using numbers to record interesting observations of their surroundings, learning simple tricks and strategies.**
   - a. "It takes practice to see the numbers behind our observations. We are going to learn some simple approaches to quantifying our observations that you will be able to apply in our future explorations."
   - b. "Right now, our only goal is to use numbers to show or describe our surroundings. As long as you are doing that, you are successful."
3. **Explain the value of including numbers in nature study.**
   - a. "Using numbers is helpful. It reveals interesting patterns and leads us to questions. For example, if I measure the diameter of all the gopher holes and notice that they all fall within a certain range, I can wonder: What might be causing that pattern? Would I expect to see something different at another time of year, when the population of gophers might be a different size or when the soil is a different texture?"
   - b. "These techniques for finding numbers give you another way of exploring and figuring things out in nature."

Note: Offer one or more of the quantification techniques described in the next sections, giving students time to play around with the technique(s). Make a decision about how many of these techniques to introduce in a session. With a younger group, you might focus on just one skill (e.g., measuring) and give students extended practice and support using it. To support groups that need even more structure, give students specific things in nature to quantify (e.g., "Count all the gopher holes you can find. Now measure their diameter"). Give more independent students a few minutes to practice using each quantification approach (measuring, timing, counting, and estimating) and then a longer period of time during which they can play around and choose which approach to use. Estimation can be more challenging for younger students, so consider introducing it later, in a context where you are able to spend time devoted to offering specific approaches and dedicated practice.

Measuring

1. **Explain how students can use measuring to find out the lengths or distances between things, referencing nearby examples and referring to any available tools.**

   - a. "First, we are going to look at measuring. We can measure almost anything we find! Getting data on the lengths or distances between things can reveal interesting patterns."
   - b. "For example, you could measure the size of leaves on a bush, the distance between leaves, the length of a scar on a tree, the distance between plants, the width of holes in the ground, or the distance from tree to riverbank in different areas."
   - c. "Try to choose clear points to start and end your measurements. For example, measuring the distance between branches and starting your measurement in middle of a branch could cause confusion—measuring from where both branches emerge from the tree has a clear start and end point."
   - d. Offer any tools you have for measuring, reminding students to be careful and to share materials.
2. **Tell students to pick a nearby natural object and measure as many parts of it as possible, recording their data in their journal and adding sketches, writing, and questions if necessary.**
   - a. "Go pick something to focus on and write and draw about it a bit in your journal. Then see how many different parts of it you can measure, and record your measurements in your journal."
   - b. "Numbers are great for leading us to questions. Intentionally ask questions based on your measurements as you go. What is the most interesting question that comes to you?"
   - c. "If you want to switch topics and measure something else instead, that's fine, too. You have four-and-a-half minutes. Go!"
3. **After students have had some time to measure, but before they lose interest, call them back and debrief measuring, leading a brief discussion using the questions here.**
   - a. "How did that go? What kinds of different things did you measure? What was your most creative measurement?"
   - b. "Did you notice anything that surprised you? How did measuring help you learn about what you were looking at? Did your measurements lead to any questions?"

Timing

1. **Explain how students can use timing to record anything in motion, referencing nearby examples and appropriate tools and techniques for your setting.**

a. "Let's look at timing. We can time anything in motion."

b. "For example, can use timing to learn about animals. If we see an animal repeating a behavior, we can time the intervals between behaviors. If we see a hawk flying above us, we can time how long it soars before flapping its wings. We can time how long the sparrow's call is. If we see a duck dive underwater, we can time how long it is until it comes up."

c. "If there are interesting weather patterns, we can also time them. For example, we can record the amount of time between gusts of wind, or how long it takes one quickly moving cloud to pass over the horizon."

d. "If you have a stopwatch, you can use that to record timing. If you don't have a stopwatch, you can count the seconds yourself. A second lasts about as long as it takes to say, 'one hippopotamus.'"

2. **Tell students to find things to time nearby, and to record their data in their journal, asking questions and using writing or pictures to show their observations when necessary.**

   a. "Find things nearby to time."

   b. "Record what you time in your journal. Intentionally ask questions based on your measurements as you go. What is the most interesting question that comes to you?"

   c. "If written notes or drawings would be helpful, you can add them. You will have four-and-a-half minutes to time whatever you can. Go!"

3. **(Optional) Call students back and introduce the process of using time and distance to calculate speed; ask students how they might time the speed of a banana slug, then explain that they must calculate distance over time.**
   Note: **This will be most appropriate for older students.**

   a. "How might you calculate the speed of something like a banana slug?" (Hear student responses.)

   b. "For this type of timing, you must measure the distance that the slug covers over a period of time. You could put a stick next to the slug as a marker, and a second stick after one minute. Then, measure the distance between the sticks."

4. **After students have had some time to measure, but before they lose interest, call them back and debrief timing, leading a brief discussion using the questions here.**

   a. "How did that go? What kinds of different things did you time? What was the most creative way you thought to time something?"

   b. "Did you notice anything that surprised you? How did timing help you learn about what you were looking at? Did your timing lead to any questions?"

5. **Explain that for faster processes, a stopwatch is a good tool, but for longer processes, such as a leaf changing color, a calendar is better.**

   a. "Some things, such as a leaf changing color, occur on a time scale that is too long for us to observe with a stopwatch, but we could time this phenomenon and other longer-term processes over the course of days or weeks, with a calendar instead of a stopwatch."

   b. "Consider the units for your timing when you write down numbers in your journal.When might seconds be appropriate? When might we use days or weeks?"

Counting

1. **Explain how counting is a way of observing that reveals interesting patterns, and point out nearby examples of what students could count.**

   a. "As soon as we start counting, we reveal patterns that we can then think about and use to better understand our surroundings."

   b. "We can count numbers of individual organisms, such as the number of lizards sunning on the rock, the number of anemones in each tide pool, or the number of spider webs on a tree. We can also count the number of parts of organisms, such as the number of pine needles in each bundle, the number of spines on an oak leaf, or the number of spots on different ladybugs."

   c. "You can also count nonliving parts of the landscape, such as holes in the ground."

2. **Explain that while counting, it's important to include the context. (For example, is it the number of ladybugs found on one single bush? across a field? over the course of a day?)**

   a. "When you record what you have counted, you need to add some context. For example, for a number of ladybugs, you need to specify: Is it ladybugs found on a bush, across a whole field, or seen over an entire day?"

3. **Tell students to find things to count nearby, recording their data in their journal, asking questions, and using writing or pictures to show their observations when necessary.**

   a. "Try counting as many different things as you can. Record what you find in your journal and add writing and drawing if it is helpful. Include any questions that come to you."

4. **After students have had some time to count, but before they lose interest, call them back and debrief counting, leading a brief discussion using the questions here:**

   a. "How did that go? What kinds of different things did you count? What was the most creative way you thought to use counting?"

b. "Did you notice anything that surprised you? How did counting help you learn about what you were looking at? Did your counting lead to any questions?"

Estimation

1. **Explain when and how students might want to use estimation to gauge large numbers, distances, percent cover, and other values that would be difficult to count or measure.**

   a. "Sometimes it isn't possible to count or measure."

   b. "Maybe there are so many leaves it would be difficult to count them all, or maybe the birds are moving too fast to count each one. Or maybe we want to get a sense of how much of the sky is clouded over, and counting the number of clouds will not reveal this information."

   c. "In these situations, we estimate. Estimation isn't just guessing; it's using a specific approach to make as accurate of a guess as possible."

2. **Offer strategies for estimating large numbers, using the "number dots" (p. 200) in the "Numbers and Quantification" section as a tool.**

   a. "One approach for estimating large numbers of individuals is to count just ten, see what that looks like, then count how many chunks of ten seem to be present."

   b. (Show the "number dots" on p. 200.) "You can also use this chart that shows what ten, fifty, one hundred, and five hundred look like to help you estimate."

3. **Offer strategies for estimating percent cover, using the "percent cover" chart (p. 200) in the "Numbers and Quantification" section as a tool.**

   a. (Show the "percent cover" chart on p. 200.) "To estimate something like the amount of sky covered by clouds or the amount of ground covered by snow, use this chart to make a quick guess."

If you and your students find some insects on a leaf, these are examples of the kinds of quantification questions you can ask:

- How many bugs?
- How many instars (age/size classes)?
- How many bugs in each stage of development or life-cycle phase?
- What proportion of the plants in the area are infested with bugs?
- Can you find insect-damaged leaves?
- Can you quantify levels of leaf damage?
- Is there a correlation between number of bugs and leaf damage?
- Can you group the bugs by color?
- How many bugs are in each color class?
- Does color correlate with size?
- Are there more bugs above or below the leaves, at the top or base of the plant, or in the shade or sun?

Then ask why…

4. **Tell students to go out and quantify nearby parts of nature, counting exactly if possible, estimating to determine large numbers, and recording estimates in their journals.**

   a. "Go out and find some things to count or estimate. If you are able to count something exactly, go for it. If you can't, then use estimation to help you. Notice in what situations it is better to estimate than count."

b. "Record what you find in your journals. Keep your estimate rounded off. If you count around a hundred ducks and then see two more, Say 'about one hundred,' not 'one hundred and two.'"

5. **After students have had time to estimate but before they lose interest, call them back and debrief estimation, leading a brief discussion using the questions here.**

   a. "When did you choose to estimate something rather than get exact data?"

   b. "Did you notice anything that surprised you? How did estimating help you learn about what you were looking at? Did your counting lead to any questions?"

Quantification Practice

1. **Instruct students to explore the nearby area, using their new quantification skills to record data about anything that is interesting to them, and including words or pictures when necessary.**

   a. "In a moment, you will get to apply your quantification skills by exploring anything that is interesting to you."

   b. "Record observations in drawing and writing, and look for ways to count, estimate, measure, or time what you are looking at. This takes creativity. See if you can discover interesting or unexpected opportunities for quantification."

   c. "You could use all these approaches to quantification or focus on just one that you think is particularly fun or interesting."

   d. (Optional: if you have taught students how to visualize data—e.g., graphs, histograms, scatter plots) "Whenever possible, visualize your data."

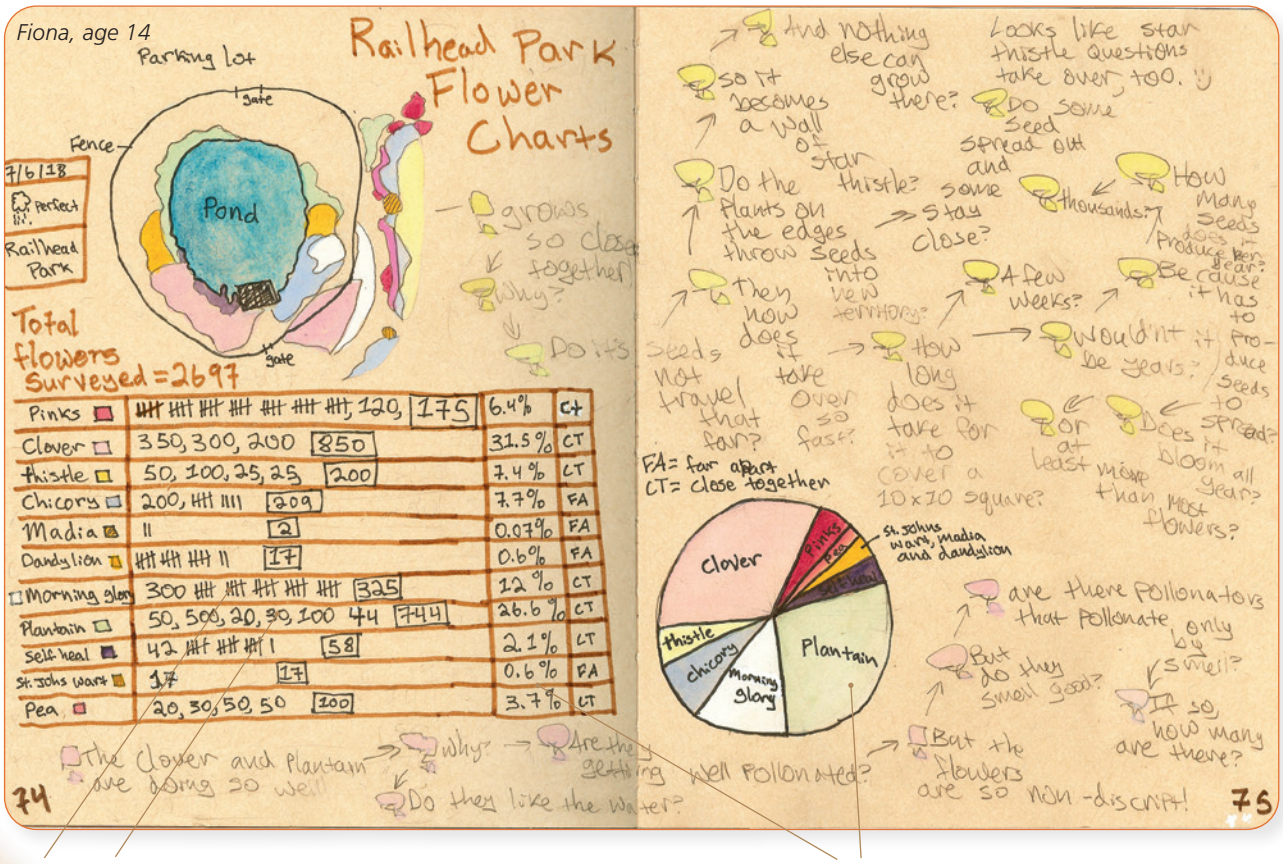
2. **Explain that there is no penalty for being wrong or making a mistake, because the goal is to see how many ways students can use numbers to describe their surroundings.**

   a. "The more relevant numbers you find, the better, but there is no penalty for making a mistake. Just try things out. Our goal is to see how many ways we can use numbers to describe our surroundings."

3. **Ask if there are any questions, reference any available measuring tools, and send students out to practice quantification.**

   a. "When we return, we will see how we found the hidden figures in our observations. You will have ten minutes. Does anyone have any questions before we start?"

   b. (Optional) Set out an array of measuring tools that students may use. You may want to introduce the tools one at a time in class under more controlled conditions. (New tools are often a distraction.) Set clear expectations about bringing the measuring tools back at the end of the study.



Counts and approximations of numbers of plants in a study area, tied in to a color-coded key and map

Plant numbers converted to percentages and displayed on a pie chart

DISCUSSION

Lead a discussion using the general discussion questions and the Science and Engineering Practices (SEP) questions. (For more information about SEPs, see page 239 in the section "Journaling and the NGSS.") Intersperse pair talk with group discussion.

General Discussion

Call the group back and debrief the experience, asking students to share what they noticed through quantification, and any questions that arose.

a. "Look at your numbers. What did you notice? Did quantification help you reveal any interesting patterns? What were they?"

b. "Did you come up with any interesting questions as you were quantifying? What were they?"

c. (If students didn't come up with any questions) "Now use your quantitative data to come up with as many questions as possible. We can use quantification to reveal patterns and ask questions."

Using Mathematics and Computational Thinking

Ask students questions about the kinds of observations they were able to make using numbers, and how they might integrate numbers into their future journal entries.

a. "What did you notice in your explorations? What did you learn by using numbers to describe your observations?"

b. "What could you measure, count, estimate, or time while doing a journal entry on plants? animals? the weather?"

ADVANCE OR FOLLOW-UP ACTIVITIES

Practice Estimation

You can have students practice estimating numbers by throwing beans on a blanket, doing a quick gut estimate, making an approximation roughly counting by 10s, 50s, or 100s, and then making an exact count. This will help students develop the skill of quick estimation and will also be an opportunity to see how accurate your students are. Do they tend to estimate too high or low?

Collect Biometrics

Measure and record students' metric or standard biometrics for measuring without tools: shoe length, distance traveled in one regular step (averaged over 100 feet or 50 meters), distance traveled in ten steps, knee height, navel height, total height, arm span, number of steps needed to travel 10 meters and 100 feet. Then go out and measure and estimate objects near your home or school.

Find the Numbers

Show examples of naturalists' or scientists' journal entries that use numbers along with other modes of recording information. Engage students in discussion about how quantification is used, what types of things are quantified, and how this works with other modes of recording information to show observations and thinking.

Record Data over Time

Engage students in long-term scientific studies that involve mathematical thinking and data collection. Connect field methods for gathering data to this activity.