AAAS ScienceNetLinks

Finding the Surface Area of a Leaf

WHAT YOU NEED

- **Frayer Model**
STUDENT ACTIVITY SHEET
- **Surface Area of a Leaf**
STUDENT ACTIVITY SHEET | HANDS-ON
- **Frayer Model Teacher Sheet**
TEACHER SHEET
- **Surface Area of a Leaf Teacher Sheet**
TEACHER SHEET | HANDS-ON

MATERIALS

- Notebook
- Pencil
- Calculator
- A variety of leaves from different plant species
- 4-5 photo copies of each leaf that will be used for the investigation
- Photos of plant species from which leaves were collected
- Metric ruler
- *Seed, Soil, Sun: Earth's Recipe for Food* by Cris Peterson

Optional

- Grid paper for each student or student group (centimeter or other grid size)

Optional Reading

- **The Glory of Leaves (http://ngm.nationalgeogr text)**

PURPOSE

To explore the importance of math modeling and precision through a leaf surface area investigation.

CONTEXT

"To make sense of the world, the human mind relies heavily on its perception of shapes and patterns. The artifacts around us and the familiar forms we see in nature can often be characterized in terms of geometric shapes. Although real-world objects never perfectly match a geometric figure, they more or less approximate them. As a result, what is known about geometric figures and relationships can be applied to objects." [*Atlas of Science Literacy*, Volume 2, p.66]

This lesson was developed by Dr. Daniel (Timothy) Gerber, of the University of Wisconsin–La Crosse, in association with Dr. Jenni McCool, also of the University of Wisconsin–La Crosse, and Ms. Megan Wagner.

This lesson gives students an opportunity to approach area, leaf surface area specifically, in a real life context and allows your students the opportunity to discuss and apply knowledge of geometry in a meaningful way. While the main learning goal is for students to understand that for regularly shaped objects, relationships exist between the linear dimensions, surface area, and volume, students also will learn about leaves in general. The growth of a leaf in length not only increases its surface area by the square of the linear dimension but also adds mass, which is biologically significant. In addition, since the lesson's focus is on relatively flat leaves of deciduous trees and not the thicker needles of coniferous trees, there is an interesting relationship between growth in length and volume, which increases by the cube of the linear dimension and has additional biological consequences that are beyond the scope of this lesson. This lesson's focus on the use of measurement tools, precision, and reasoning offers a context for the type of instruction needed to grow students' geometry and measurement knowledge while applying these skills to understand how leaves function. The lesson addresses a misconception that students may have related to measurement tool use. Students often use measurement tools in a rote manner, not fully understanding how the tool actually relates to the units on the tool (Lehrer, 2003).

After fifth grade, students should have a basic understanding of the "shapes in the real world" strand where "length can be thought of as unit lengths joined together" and "area as a collection of unit squares." [*Atlas for Science Literacy*, Volume 2, p.67] This lesson will help prepare students for the more abstract concept of approximating real objects that do not match a perfect geometric figure. This also prepares students for a better understanding of the relationships between linear, area, and volume dimensions needed in grades 9-12.

In order to guide instruction to meet the needs of learners and assess understanding, Dina and Pierre van Hiele (1999) created five levels that characterize students' thought progress as they learn geometry. Three levels most commonly seen in middle school include: Visualization, Descriptive, and Informal Deduction. At the most basic level, Visualization (Level 1), students identify geometric figures by their appearance and not by their properties. At the Descriptive Level (Level 2), students can identify properties of figures, analyze figures based on those properties, and make generalizations about shapes as they relate to other shapes. The third level, Informal Deduction, describes student thinking that includes the development of abstract definitions, the ability to make informal arguments, and the ability to create hierarchies to classify shapes. Given traditional geometry instruction, students in middle school tend to be at a van Hiele level of one or two (Clements and Batista, 1992). This lesson addresses the need for students to increase their van Hiele level of understanding; this is where instruction is critical.

PLANNING AHEAD

Before you begin the lesson, students should have background knowledge about surface area and how to find the area for basic shapes. The correct use of measuring tools to find lengths and areas is necessary. So students should practice with the tools you have prior to working on this lesson. Students also should have a basic understanding of the parts/structure of a leaf, including the leaf blade and leaf petiole (leaf stalk). Use flat leaves of deciduous trees or shrubs, herbaceous plants, or ferns and not the thicker needles of coniferous trees for this lesson. Deciduous leaves are generally thin and have both an upper and lower surface. For this lesson, students will find the upper leaf surface area. However, both the upper and lower leaf surfaces can be measured. It is important to be consistent. So make sure students know what is to be measured.

MOTIVATION

The artifacts around us and the familiar forms we see in nature can often be characterized in terms of geometric shapes. Begin the lesson with the question, "What is a leaf?" To initially assess students' prior knowledge of a leaf and determine any barriers that may hinder learning about leaves, a Frayer Model should be given to each student (see the **Frayer Model** student sheet). Have students discuss their responses to the question "What is a leaf?" and create a Frayer Model for a leaf. Discuss students' Frayer Models as a class. You can use the **Frayer Model** teacher sheet to help you guide the discussion. Ask students the question, "Why does the size of a leaf matter?" In small groups of four, students should brainstorm why they think surface area would be an important characteristic of a leaf. Pass different leaves around to groups. Students should discuss similarities and differences among the leaves. Also ask how they would describe the overall shape of each leaf.

DEVELOPMENT

Read the book, *Seed, Soil, Sun: Earth's Recipe for Food* by Cris Peterson as a class. Then ask students to compare their definition of a leaf based on their Frayer Models to the definition of a leaf given in the book. They should revisit their Frayer Models and make any necessary changes so their definition of a leaf is accurate. Then students should explore geometric shapes that most closely resemble the illustrations of leaves in the book. Here is a great opportunity for students to think about either the overall shape of a leaf or breaking a leaf into various geometrical shapes. For further exploration, an incredible variety of leaf shapes, sizes, colors, etc. can be found in the book, *Extraordinary Leaves*, or use the online **USDA Plants Database (http://plants.usda.gov/java/)** image gallery. In addition, **The Glory of Leaves (http://ngm.nationalgeographic.com/2012/10/leaves/dunn-text)** is a good article written for a general audience explaining the biological function of leaves and nicely provides a stronger science connection to this lesson.

Next, hand out a variety of leaves from different plant species or ask your students to bring leaves to school. Again, students should explore the shapes of real leaves. Ask students, “Why might someone want to know the surface area of a leaf?” If they need a prompt, have them think about photosynthesis. Light, water, and carbon dioxide gas are all necessary for photosynthesis to occur. By absorbing light and taking in water and carbon dioxide, the leaf will produce excess oxygen and food the plant needs for growth. Light is absorbed by leaves and differences in surface area exposed to light can change the rates of photosynthesis. Carbon dioxide is absorbed into a leaf through stomates, which are found on its surface. Water also is lost from a leaf through its stomates so plants with a large surface area can lose large amounts of water. By the end of the discussion, students should come to see that in general, differences in leaf area can affect photosynthesis and therefore, the production of oxygen and food a plant can generate. Again, students should explore geometric shapes that most closely resemble the real leaves in your classroom. Here is another great opportunity to think about either the overall shape of a leaf or break a leaf into various geometrical shapes and then estimate leaf surface area by calculating the area of the related geometric shape(s). Does the geometric shape(s) over- or under-estimate the area of your real leaves?

While the students still have real leaves available, divide students into groups and hand out 4-5 different photocopied leaves to the groups of students. Each group should receive the same 4-5 species of leaves so areas can be compared later in the activity. Ask students to find the area of their leaves using square centimeters and record their solutions and methods. Students should use the **Surface Area of a Leaf** student sheet for this exercise. Provide rulers, string, pencils, scissors, etc. Encourage students to use whatever materials they need to find the area; however, let them try to figure out the surface area of their leaves on their own. After students have estimated the surface areas of their leaves, they should compare their data and solution methods with the other groups.

Note: For lower learners, students can trace the leaves on centimeter grid paper. Then they should outline the leaves in a dark color to make it easy for them to see. Next, students can count how many whole grid squares were in the leaves. Then they should count the number of partial squares and divide that number in half to get an approximate number of additional square centimeters. Please see the examples of this process in the **Surface Area of a Leaf** teacher sheet.

Discuss as a whole class the strategies used and the merits of each strategy. A discussion about the importance of estimation and measurement precision should ensue. Ask, “Can you think of situations where estimation and precision in making measurements is more/less important than other times?”

Additional discussion questions to consider include:

- How does the size of the leaf influence the measurement method or scale?
- Think about how you would measure the area of a palm frond as compared to how you would measure the area of a clover leaf. Would you use different tools to measure these two different leaves? How would you go about measuring them?
- How accurate does the measurement need to be?
- Is there a specific model to be tested? If so, what is the uncertainty in the model predictions?

(Answers may vary. Encourage students to explain their answers.)

ASSESSMENT

One way to assess student understanding would be to ask them to do a Frayer Model again to graphically organize knowledge into four sections, including: an operational definition, characteristics, examples, and non-examples (Buehl, 2001). This formative assessment tool can also be used to "help solidify conceptual understanding after students have had an opportunity to learn about the concept." (Keeley, 2008)

Another way to assess student understanding would be to ask students to complete the sentence, "I used to think…but now I know…" This activity would help show students' preconceived ideas versus what they have now learned after the exercise.

Finally, you could ask students to describe two methods for finding the surface area of a leaf and describe two types of leaves that would be best measured using each of the two methods.

EXTENSIONS

This lesson can be extended to find the surface area of a leaf using proportional reasoning. For higher learners, you could have students photocopy a leaf onto a sheet of paper, cut it out, and weigh the leaf using a balance scale. Then, they should cut a rectangle out of the same type of photocopy paper used for the photocopy of the leaf and weigh the rectangle. Students should continue to cut off strips of the rectangle until the rectangle has the same mass as the photocopied leaf. The use of a rectangle allows students to quickly calculate the area of a familiar shape. Now that the mass of the two objects is known, as well as the area of one object, students can find the area of the leaf in a more precise way using proportional reasoning. Students can then compare their original area measurement with that of this more precise measurement.

For higher learners, a possible extension is to have students draw leaves on grid paper at normal (1X), 2X, and 0.5X sizes in leaf length. Changes in leaf surface area increase or decrease by the square of the increase or decrease in length. Therefore, a leaf that is drawn twice the size in length (2X) will have a surface area that is four times the original surface area. This provides an excellent way to demonstrate the mathematical relationship between length and area. If you prefer not to draw, photocopy the same leaf at 50% (0.5 X), 100% (normal or 1X size), and 200% (2X). Then have students measure the leaf length and surface area at each size. What is the relationship of length to area as size increases?

Fractal Dimensions of Leaf Shapes (http://www.math.tamu.edu/~mpilant/math614/StudentFinalProjects/SanPedro_Final.pdf) is an activity in which students can analyze leaf shapes in terms of fractal geometry.

To take this lesson further, a mathematical modeling extension could be done with students to determine the surface area of a canopy of leaves on a tree. Begin this activity or research project by asking, "How might someone estimate the total surface area of the entire canopy of a tree? Once we have this information about tree canopy surface area, how could we use that information to determine the weight of the entire canopy on that tree?" Assumptions that students make about this situation should be documented as part of a written or verbal explanation of how their group found the answer. Tools students may need for this task include access to the trees the leaves came from, even if they simply have a photo of a tree. Trees on the school grounds could potentially make good subjects for this research project. What is the surface area of all of the leaves on all of the trees at school? What is the weight of all of the leaves in these tree canopies? Do different tree species have differing total leaf surface areas? Do older trees have differing total leaf surface areas than young trees of the same species?

Resources:

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- KEELEY, P. (2008). *SCIENCE FORMATIVE ASSESSMENT. 75 PRACTICAL STRATEGIES FOR LINKING ASSESSMENT, INSTRUCTION, AND LEARNING.* THOUSAND OAKS, CA: CORWIN PRESS.
- LEHRER, R. (2003). DEVELOPING UNDERSTANDING OF MEASUREMENT. IN J. KILPATRICK, G. MARTIN & D. SCHIFTER (EDS.), *RESEARCH COMPANION TO PRINCIPLES AND STANDARDS FOR SCHOOL MATHEMATICS.* RESTON, VA: NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS.
- PETERSON, C. (2010). *SEED, SOIL, SUN.* (2012 SB&F CHILDREN'S SCIENCE PICTURE BOOK PRIZE FINALIST) **HTTP://WWW.SBFONLINE.COM/SUBARU/PAGES/FINALISTS2012.ASPX (HTTP://WWW.SBFONLINE.COM/SUBARU/PAGES/FINALISTS2012.ASPX)**
- VAN HIELE, PEIRRE M. (1999). DEVELOPING GEOMETRIC THINKING THROUGH ACTIVITIES THAT BEGIN WITH PLAY. *TEACHING CHILDREN MATHEMATICS 5*; 310-316.

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