~ Spirals & Small Spaces ~
A Fibonacci STEAM Activity
by Tania Marien


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Part 1: "Spirals & Small Spaces"
Part 2: "Be a Science Communicator!" (page 8)

Appropriate for grades 7-12

Synopsis of the Activity
Students will learn about Fibonacci and the number sequence he described. They will observe and count Fibonacci spirals in plant specimens, create a model demonstrating the benefit of spiral arrangements in small spaces, and apply what they learned in making a "scientific illustration" (doodle/sketch) of a pineapple, pinecone, or artichoke.

Activity (Learning) Goals
- Students will identify Fibonacci spirals in plants.
- Students will create small models of Fibonacci spirals to see for themselves that spiral arrangements can accommodate more elements (i.e., bracts, flowers, seeds).
- Students will learn the pattern of the Fibonacci sequence.
- Students will apply what they've learned in the way that a scientific illustrator would apply the same information (with a scientific illustration of a pinecone, pineapple, or artichoke) to communicate information about these specimens in a visual way.

Concepts
- Nature can fit more structures in a small space if they are arranged in spirals.
- Fibonacci is a number sequence.
- Fibonacci spirals can be observed in plants (and other objects)
- Science communication occurs not only in a written format, but visually too.

Introduction to the Fibonacci Sequence

The Fibonacci sequence arose from a thought experiment conducted by Leonardo of Pisa (aka “Fibonacci”), published in 1202. Fibonacci contemplated this question:

“How many pairs of rabbits will there be at the end of one year, if a young mating pair were able to mate at one month of age so that at the end of month #2, the female rabbit could produce another breeding pair of rabbits?”

The answer is an ongoing sequence of numbers that follows a specific pattern. This pattern looks like the sequence below:

1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144…

Note that each number in the sequence is the sum of the two numbers preceding it. While Fibonacci’s “what if” question might have been fun for him to entertain, it can never be tested because rabbit biology doesn’t really work this way.

However, the resulting sequence appears repeatedly in nature and other areas of real life. You will find the sequence represented in the spiral arrangement of bracts in pinecones, seeds in the heads of sunflower plants, and in the arrangement of fused fruit on a pineapple (see Garland, 1987).

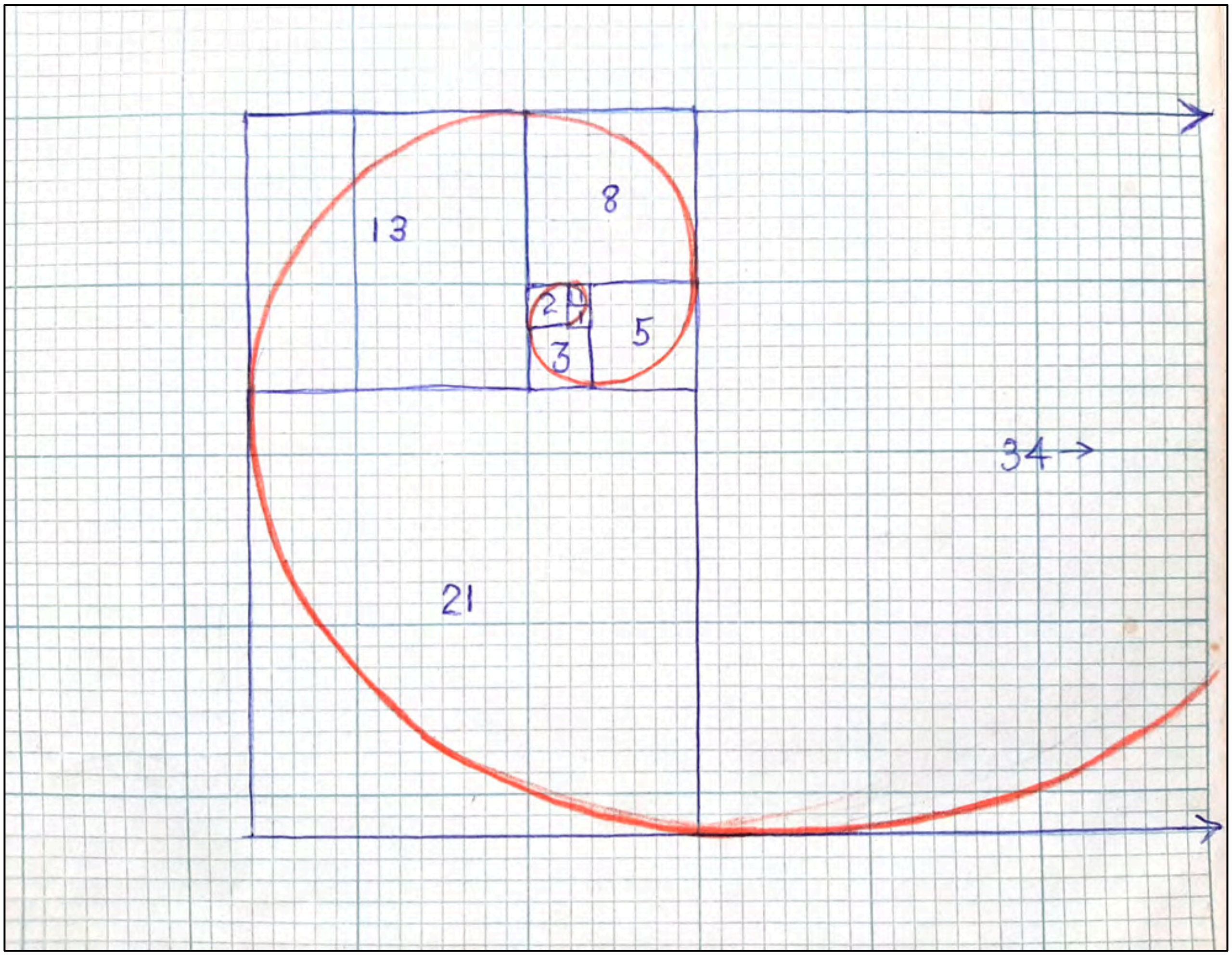
The Fibonacci sequence can also be viewed in the branching patterns of stems, in nautilus shells, in art, architecture, music, poetry, science, and technology (Garland, 1987).

For a fun introduction to the Fibonacci sequence, please watch the entertaining math tutorials produced by Vi Hart at https://www.youtube.com/watch?v=ahXIMUkSXX0.

Vocabulary (Key terms that will be defined and used in the activity)

- Fibonacci - Leonardo of Pisa (c. 1170 - c.1250), an Italian mathematician
- sequence - the following of one thing to another
- inflorescence - a cluster of flowers (refers to the pineapple)
- bract - a leaf-like structure (refers to pinecones and artichokes)

The Fibonacci Sequence Graphed as a Spiral



drawing by Sally Bensusen

Applicable Standards

Next Generation Science Standards

K-LS1 From Molecules to Organisms: Structures and Processes

Science and Engineering Practices

- Use observations to describe patterns in the natural world in order to answer scientific questions (K-LS1-1)

MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

Science and Engineering Practices

- Develop and use a model to describe phenomena. (MS-LS1-2)

Common Core State Standards

- Math K.MD.A.2
  Directly compare two objects with a measurable attribute in common, to see which object has "more of" or "less of" the attribute, and describe the difference.

National Core Arts Standards

- Essential Questions: How do artists and designers create works of art or design that effectively communicate? How does making art attune people to their surroundings?
- Enduring Understanding: Individual aesthetic and empathetic awareness developed through engagement with art can lead to understanding and appreciation of self, others, the natural world, and constructed environments.

  - Explore the world using descriptive and expressive words and art-making
  - Develop a work of art based on observations of surroundings
  - Use observation and investigation in preparation for making a work of art
  - Perceive and describe aesthetic characteristics of one's natural world
  - Utilize inquiry methods of observation, research, and experimentation to explore unfamiliar subjects through art-making
  - Analyze how one's understanding of the world is affected by experiencing visual imagery.

Part 1 – Spirals & Small Spaces

Materials
- 2 tables
- 2 plastic tablecloths
- Blackboard, or one easel holding a whiteboard wrapped in bulletin board paper
- Pencils
- Colored pencils
- Pinecones (one for each student)
- 6 pineapples (or enough for students to share)
- 6 artichokes (or enough for students to share)
- Colored masking tape
- Plastic eggs (2 per student — these are about the size of a real egg)
- Stickers, 3” x 3” (enough for everyone in class, plus extra.)
- Dot stickers (1008 qty.)
- Examples of pinecone illustrations in field guides
- Examples of pineapple illustrations in economic botany books, botany books, cookbooks
- Examples of artichoke illustrations in cookbooks, gardening books
- Reference photos of Fibonacci sequence at work in different disciplines.

Set-up

Set up tables (Covered with plastic tablecloths):

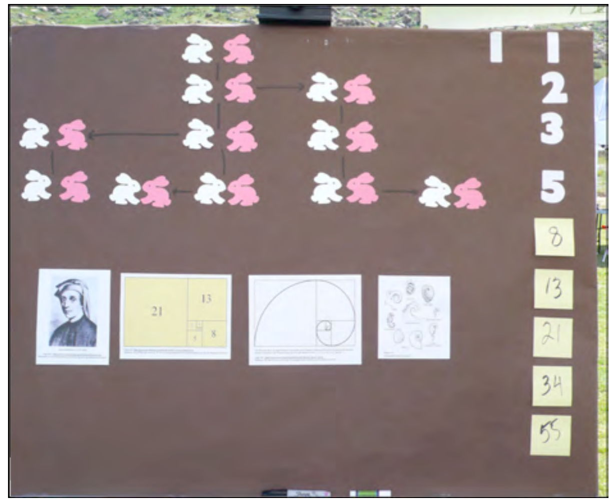
Table #1 – The Discovery Table

This table is where students will count Fibonacci spirals, explore the capacity of spiral arrangements, and learn about the Fibonacci number sequence. The following items need to be placed on this table:

- Pineapples, pinecones, artichokes
- Colored tape
- Plastic eggs
- Dot stickers

Guiding questions for Table #1:

- What do pinecones, pineapples, and artichokes have in common?
- How many spirals do you see?
- How many spirals do you see going in the opposite direction?
- Did you know that you can predict the number of spirals?
- Why do you think these structures are arranged in a spiral?



<u>Blackboard or Bulletin Board Easel</u>
This board will be set off to the side so that students can stand around the table to work and interact with each other. The Fibonacci sequence will be noted on the board (or easel), as it pertains to the flow chart depicting Fibonacci's rabbits. (right)

<u>**Table #2** – Fibonacci's Tablecloth</u>
The butcher paper on this table will be referred to as "Fibonacci's Tablecloth". This is where students will doodle/sketch a pineapple, pinecone, or artichoke on the "tablecloth."

Activity Description

1. **Introduction.** Invite students to the table by asking them what they think the pinecone, pineapple, and artichoke have in common. Write their guesses on the blackboard (or on the whiteboard w/markers).

2. **Spiral Search.** Introduce students to the spirals observable in the displayed specimens. Demonstrate how they can mark the spirals using colored tape. Ask them if they see spirals going in the opposite direction. Ask them to mark these spirals using tape of a different color.

Spirals are marked in pen on this photo.

3. **Spiral Spaces.** Ask students why they think the spirals exist. Explain that spiral arrangements can hold more elements (i.e., bracts, seeds, flowers, etc.). Invite students to explore this by covering one plastic egg with dot stickers any way they want (but without overlapping the dots). Then invite them to methodically arrange dot stickers in a spiral arrangement on the second egg. Ask them to count the number of dots on each egg.

4. **Did You Know…** Lead a conversation: If you know the number of spirals going in one direction, you can estimate the number of spirals going in the opposite direction. Explain the Fibonacci sequence and ask students what they think the next number in the sequence will be.

Teaching Strategies: The Learning Cycle and Fibonacci Activity

1. **Invitation.** Ask students an introductory question bringing attention to the specimens on the table: *What do pinecones, pineapples, and artichokes have in common?* Write student responses on the blackboard (or whiteboard w/markers).

2. **Exploration.** Guide students through two exploratory exercises. One focuses on counting spirals. The other involves predicting the next number in the Fibonacci sequence.

3. **Concept.** Lead into this by explaining that Nature can fit more structures into small spaces if they are arranged in a spiral. This component invites students to investigate this themselves by placing sticky dots on plastic eggs, or on cylinders. (Eggs are preferred, because they more closely resemble the general shape of pinecones, pineapples, and artichokes.) Students would cover one egg with sticky dots haphazardly (but without overlapping them). They will then cover their second egg with sticky dots by placing the dots methodically in a spiral pattern.

4. **Application.** Discuss who would use information about the Fibonacci spirals in their work. Use this as a segue into **Part 2** about scientific illustration and how scientific illustrators use their knowledge of Fibonacci spirals to draw spirals in illustrations of pinecones, pineapples, and artichokes for resources such as field guides. After showing examples, invite students to sketch (doodle) a pinecone, pineapple, or artichoke on "Fibonacci's Tablecloth" covering **Table #2**. The incentive will be to add to the community tablecloth.

   (*See the alternative application, "Be a Science Communicator!",* ***Part 2****, p. 8.*)

5. **Reflection.** Revisit your students' original thoughts about what the pinecone, pineapple, and artichoke have in common (i.e., revisit the white board).

   (Or, if you didn't write down students' guesses, revisit their earlier predictions verbally before the end of class.)

   Ask students why knowing the Fibonacci sequence matters in everyday life.
   - Explain that the sequence appears in different disciplines (refer to reference photos).
   - Tell them that now that they know about Fibonacci spirals, they can introduce others to Fibonacci spirals the next time they draw pinecones, pineapples, and artichokes.
   - Tell them their new knowledge will make their own drawings (i.e., scientific illustrations) very informative. Invite students to apply this new knowledge by contributing to Fibonacci's Tablecloth on **Table #2**.

<u>Part 2</u> – Be a Science Communicator!

A Brief Introduction to Scientific Illustration

You have already learned a lot from scientific illustrators even though you may not have been aware of it. *Scientific illustrators* are the people responsible for the images in biology books, health books, and even in social studies books!

Scientific illustrators work in many different fields. The scientific illustrators who work with plants are called botanical illustrators. Those who work on medical issues are called medical illustrators. Some scientific illustrators focus on birds. This is called ornithological art.

Some scientific illustrators work on archeological sites. These illustrators sketch artifacts and dwellings, for instance, found onsite. They sketch objects like fragments of broken pots, the patterns on pieces of fragments, and arrowheads.

(Consider showing books in class, including the GNSI Handbook, first edition [see bibliography], pp. 402–403. Show examples of medical illustrations, pp. 427–428.)

We see the work of scientific illustrations in textbooks, yes, but we *also* see them at museums, on interpretive panels, in the news, and in scientific journals.

In this activity, your students will have the opportunity to be scientific illustrators!

This is where students will doodle/sketch a pineapple, pinecone, or artichoke onto a 3-inch x 3-inch sticker. The objective of this activity is to teach them about what scientific illustrators do and to help them identify *with* scientific illustration and science communication, perhaps as a potential career!

You might mention the Guild of Natural Science Illustrators. This organization is now 50 years old. (https://www.gnsi.org)

Setup

Use the same setup for **Table #1**, as you did in **Part 1**, but set up **Table #2** this way:

- Cover the table in butcher paper
- 3-inch stickers
- Conifer field guide
- How-to-draw illustrations for the pineapple (Wunderlich) (see bibliography)
- How-to-draw illustrations for the artichoke (Wunderlich)
- *The Guild of Natural Science Illustrators (GNSI) Handbook* (see bibliography)
- Pineapple economic botany information
- Artichoke economic botany information
- Botany Atlas - pinyon pine seed germination

Activity Description

1. **Invitation.** Introduce scientific illustration to the class.

2. **Procedure:** On **Table #1** are the "specimens" you provided in **Part 1** that your students will use to make their drawings, that is, their "visual notes."

   Have each student select a specimen and to hold it in his/her hand. Notice its shape, its texture. Is it round? Is it smooth? Is it pointy?

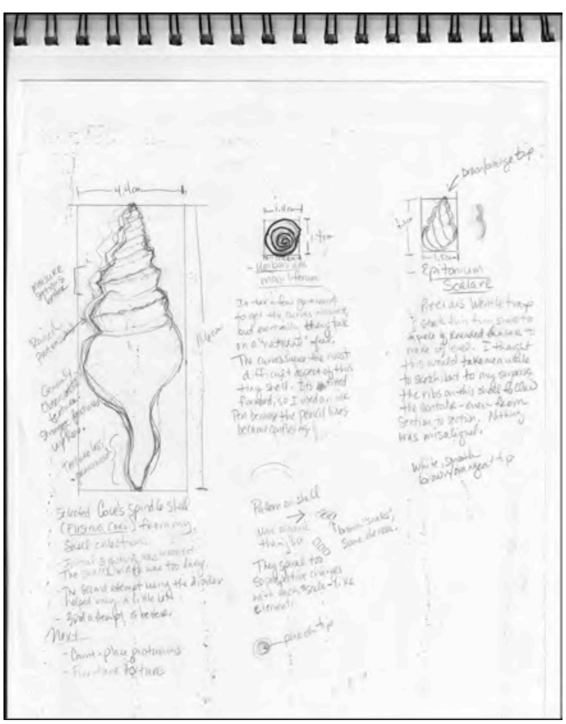
   Then notice its weight. Is it light or heavy?

   Then notice its color.

   Have them make notes of these features. They must find accurate adjectives to describe them. They will be adding these words to their sketches.

   In the center of **Table #2** table are the large 3-inch stickers. These stickers will serve each student as a "field notebook" for this activity. Have each student draw a picture of his/her specimen on this sticker.

   Important: The intent behind visual note-taking like this is *not* to make beautiful works of art. *Each of these drawings will not be a finished artwork!* These are "field studies," where the intent is to *record accurate information* about these objects. And like scientific illustrators who work in the field and who must work quickly to note down information, your students, too, have limited time and must work quickly. The sketches they will make are called gesture sketches. They are loose and fast. They look might look something like the drawing (below left) of spirals on a shell.



Gesture sketches capture the most important information about a subject, the characteristics that help describe a subject. The intent here is to capture enough information to take back with you to your lab or to your studio and look it up. There must be enough information in the drawings to be able to say to someone, "This is what I saw. It has this, and this, and this."

On each table you have provided the tools to help students do this. They will use the graphite pencils, fine black ink pens, and colored pencils to create a color study.

(Walk around and help students however they need. It might be helpful to compliment them on how well they observe. Say things like "That is good observing" or "Nicely done." Avoid saying things like, "That's pretty."

Also point out <u>why</u> you're saying "good observing." Always look for something <u>specific</u> in a student's drawing to comment on, for instance, their accuracy of detail.)

3. **Things to consider:**
   Why does the Fibonacci sequence matter in everyday life?
   - Explain that the sequence appears in different disciplines (refer to reference photos).
   - Explain how knowing about Fibonacci is important to professionals like scientific illustrators, whose job it is to communicate science.
   - Explain that scientific illustrators have to draw plants and animals accurately, because they need to accurately describe species for cataloging them.
   - Explain that if scientific illustrators understand the way a spiral goes in one direction, this helps them draw the spiral also going in the opposite direction. It helps them draw things like pinecones. Show students field guides about conifers.
   - Tell students that when they understand about Fibonacci spirals, they can introduce others to Fibonacci spirals the next time they draw pinecones, pineapples, and artichokes.
   - Tell students that their new knowledge will make their own drawings (i.e., scientific illustrations) very informative. They can draw this way for any subject!

Other Considerations for Your Classroom

Fibonacci and his rabbits is really a dense topic. Wait to see how your conversations about plant spirals grow organically. After explaining Fibonacci and plant spirals in your first session, decide what really needs to go in this section:

- How much background information do educators need?
- How much background information is there really *time* for?
- Which stories resonated with your students?
- What type of discussion was generated from the background content you did provide?
- What do you need to say to guide your students' thinking?
- What do you need to say to gently correct student misconceptions?
- What do students already know about Fibonacci? About plant spirals?
- What do students say about plants in general?

Bibliography

American Society of Botanical Artists 16th Annual International Exhibition. 2013. New York, NY: American Society of Botanical Artists. http://www.asba-art.org/exhibitions/16th-annual [Examples of Fibonacci spirals in contemporary botanical art. Examples from any source will work.]

American Society of Botanical Artists. 2011. *Colorful Edibles: A Coloring Book of the Artwork of the American Society of Botanical Artists*. New York, NY: American Society of Botanical Artists. Retrieved from: https://www.asba-art.org/shop/merchandise

Garland, Trudi Hammel. 1987. *Fascinating Fibonaccis: Mystery and Magic in Numbers*. Parsippany, NJ: Dale Seymour Publications.

Garland, Trudi Hammel. 1988. *Fibonacci Patterns in Nature*. Poster. Parsippany, NJ: Dale Seymour Publications.

Garland, Trudi Hammel. 1997. *Fibonacci Fun: Fascinating Activities with Intriguing Numbers*. Parsippany, NJ: Dale Seymour Publications.

Hart, Vi. 2011. Doodling in Math: Spirals, Fibonacci, and Being a Plant (Part 1 of 3). Retrieved from https://www.youtube.com/watch?v=ahXIMUkSXX0

Hodges, Elaine R. S. 2003. *The Guild Handbook of Scientific Illustration*. Guild of Natural Science Illustrators. Second edition. Hoboken, New Jersey: John Wiley & Sons

Klar, A. 2002. "Plant Mathematics: Fibonacci's Flowers." *Nature* **417,** 595. https://doi.org/10.1038/417595a

Lanner, Ronald M. 2002. *Conifers of California*. Los Olivos, CA: Cachuma Press

Laws, John Muir. 2007. *The Laws Field Guide to the Sierra Nevada*. Berkeley, CA: Heyday Books

McCallum, Ann. 2007. *Rabbits, Rabbits, Everywhere: A Fibonacci Tale*. Watertown, MA: Charlesbridge

Newell, Alan C. and Patrick D. Shipman. 2005. "Plants and Fibonacci." *Journals of Statistical Physics*. **121**(5/6): 937-968

Paruk, Jim. 1997. *Sierra Nevada Tree Identifier*. Yosemite National Park, CA: Yosemite Assoc.

Rushforth, Samuel R. and Robert R. Robbins, John L. Crawley, Kent M. Van De Graaff. 2012. *A Photographic Atlas for the Botany Laboratory*. Sixth edition. Englewood, CO: Morton Publishing.

Simpson, Beryl B. and Conner-Ogorzaly, Molly. 2014. *Economic Botany: Plants in Our World*. Fourth edition. McGraw Hill.

Sumrall, William and Kristen Sumrall. 2018. "Understanding by Design." *Science & Children*. National Science Teaching Association. **56**(1): 48-54 Digital issue at: https://mydigitalpublication.com/publication/?i=511523

Wunderlich, Eleanor B. 1996. *Botanical Illustration in Watercolor*. New York, NY: Watson-Guptill Publications