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Growth Patterns

Fractals, Fibonacci, and More in the Children's Garden

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For many children, patterning activities are some of their first mathematical experiences. Children use their seemingly natural ability to see patterns in their environment to begin their construction of early mathematical concepts. Many patterns can be found in the child's everyday environment: patterns of activity (wake, eat, play, nap, repeat), color patterns in a picture, or shape patterns when playing with blocks. The richest source of complex patterns, and some of the easiest to access for children, is nature itself.

Do young children understand the complex mathematics in the petals of a daisy, the Fibonacci sequence in the spiral of a pinecone, the fractal geometry in the leaves of a fern, or the "golden ratio" in the seed pattern of a sunflower? Probably not, but they certainly can observe and recognize the patterns and compare them to similar patterns they find in nature.

> The Fibonacci numbers are Nature's numbering system discovered by the Italian mathematician Leonardo Fibonacci. They appear everywhere in Nature, from the leaf arrangement in plants, to the pattern of the florets of a flower, the bracts of a pinecone, or the scales of a pineapple. The Fibonacci numbers are therefore applicable to the growth of every living thing, including a single cell, a grain of wheat, a hive of bees, and even all of mankind. In the seeming randomness of the natural world, we can find many instances of mathematical order involving the Fibonacci numbers themselves and the closely related "Golden ratio" elements.[1]

Emergent mathematics in a preschool classroom incorporates many patterning activities. Children look for and find many patterns in their surrounding environment. They are also adept at creating patterns themselves using manipulatives, such as

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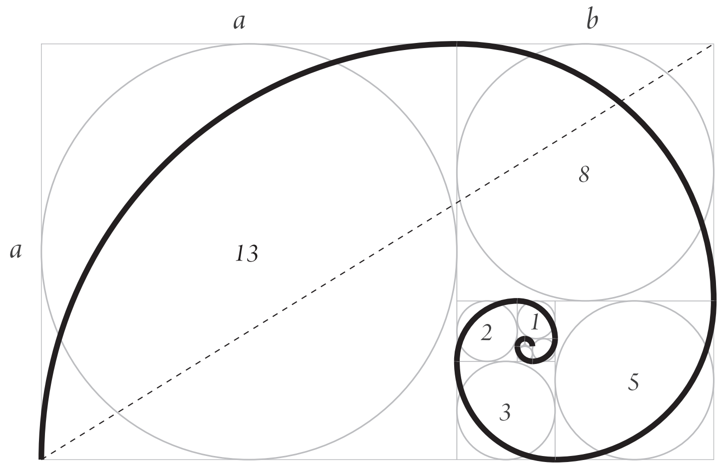
stringing beads with one white and two blue then one white and two blue over and over. This is an example of a **repeating** pattern, but some patterns are **growing** patterns. The easiest growing pattern is counting by 1s or 2s or 5s and adding "one more," "two more," or "five more" with each step.

One pattern that seems to be firmly embedded in nature is the Fibonacci sequence. The Fibonacci sequence is a set of numbers that starts with a zero, followed by a one, and proceeds based on the rule that the next number in the sequence is the sum of the preceding two numbers (0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89).

Patterns can be drawn or graphed on a piece of paper or seen visually in nature as a **ratio.** Counting by 1s gives a 1 to 1 ratio, which looks like a straight diagonal line. Counting by 2s gives a steeper line, but still straight. However, if you graph the Fibonacci sequence (0/1, 1/1, 1/1, 2/1, 3/2, 5/3, etc.) averages it is not straight; it looks like a shape found in nature (see Figure 1). The obvious relationship is to a seashell, but you can also see this pattern in a pinecone. On the pinecone, the bracts, or leaves, twist in a spiral manner in rows of Fibonacci numbers. Turn the pinecone upside down and you can see that there is a pattern to the bracts' arrangement. There are eight counterclockwise spirals that originate from the middle of the pinecone's base (see Figure 2). Counting the other way, there are 13 clockwise spirals. Both 8 and 13 are part of the Fibonacci sequence.[2]

You may be wondering how a young child can comprehend all this? Luckily, children don't have to be trained mathematicians to observe and experience these patterns in nature. All teachers need to do is to plant the seeds of inquiry and watch them grow. Starting a school garden offers one of the best opportunities to allow children to interact, observe, share, and eventually even eat the patterns of nature.

FIGURE 1



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Young Mathematicians in the Garden

Infants, toddlers, and preschoolers are learning math from everything around them, even without direct teaching. Young children may not be able to add or subtract or use other formal mathematics the way an older child can, but their interaction with a stimulating environment helps them build the basics of math. The human mind seems to be designed to find patterns and mathematics in its environment. When a child uses their own ability to learn and think about their surroundings, they naturally begin to build an understanding of mathematics.[3]

Because nature has an intrinsic underlying mathematical pattern, a garden filled with plants, flowers, trees, and other growing things is a rich place for children to observe and interact with mathematical patterns. Further, much like the flora and fauna of the garden, young children thrive in outdoor spaces. The sunshine, fresh air, and even the rain affect a child's socioemotional, cognitive, and physical development in ways that promote positive growth and development.[4] School gardens provide a context for engaging in emergent mathematics because there is always something new going on in the garden and it is filled with patterns with which children are self-motivated to interact.

FIGURE 2


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For many years, the Ohio University Child Development Center in Athens, Ohio, has maintained a garden in which various plants, flowers, and vegetables are grown. It is an integral part of the curriculum at the school; one of the central ideas of the "children's garden" is that children are included in decisions regarding managing the garden year-round. During the winter, they plan what they want to grow and design the layout of the garden. In the spring, they begin the tilling, preparing the soil, and planting the seeds. In the summer, children are responsible for watering, weeding, and pruning. They also plan a celebration of their work that will take place at the end of summer. Finally, in the autumn, children complete the final harvesting and then "put the garden to sleep" until the next spring. Throughout this time, children are observing the growth patterns of the plants. Each season brings new observations, challenges, and opportunities for exploration and discovery. Throughout all of these activities, children engage in mathematical observations and thinking.

Winter: Planning and Designing

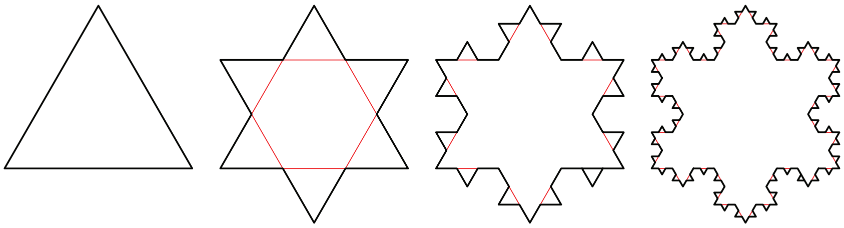
The winter may seem like a time of inactivity in the garden, but there is a lot to do and many patterns to see and create. Children still visit the garden, especially when it snows. The patterns of snowflakes not only are beautiful and a wonder to observe, but also contain mathematical patterns related to **fractal geometry** (see Figures 3 and 4).

FIGURE 4

Fractals are patterns formed from shapes that contain self-similar patterns of increasing complexity with magnification. If you divide a fractal pattern into parts, you get a nearly identical copy of the whole in a reduced size.[5] This is one of the reasons snowflakes are so intriguing to young children. The repeating patterns of fractals are evident everywhere in nature. Once children understand the idea of fractals, they will see these natural repeating patterns all around them.

Observing the garden space under differing weather and climate conditions also allows for children to learn sequential patterns, such as "before" and "after." Children can make comparisons: "Remember when the tomatoes were higher than my head?" and "Now things are brown but, in the summer, they were green!" Children draw representations of the garden while it is "sleeping" so they can compare it to drawings in spring, summer, and autumn. They also plan what they are going to grow and where. Deciding how much room to assign to various plants requires children to use their spatial awareness as they make a map of the garden. Children share their designs for the garden with each other, discussing and deciding on a final plan.

FIGURE 3



Deciding what and where to grow the plants is a school-wide process. Each classroom takes responsibility for a part of the garden. They have meetings to discuss, vote on, and decide what they want to plant. They can debate the pros and cons of each option. For example, many children want to grow tomatoes to make salsa for the garden party. Other children will point out that you also need peppers, onions, and possibly cilantro to make salsa. Some children may not like salsa and want to plant pumpkins instead. All this needs to be discussed and negotiated.

Once decisions have been made, children research the best time to plant certain things and the best place to plant them. Is there enough sun? Will the plant needs "support sticks"? How deep do we need to dig the holes? All these questions and more need answers before any actual planting can take place.

Spring: Waking the Garden Up

In the spring, children and teachers start talking about what needs to be done to re-open the garden after the long winter.

Each classroom chooses a section for the children to clean up, organize, and care for in the coming year. Spring is a flurry of activity! All the planning that has taken place over the winter will now be put into action. Digging, raking, planting, and watering are just some of the chores that the children need to do.

Again, patterns are an important part of the process. Children must decide how much room to put between each seed and between each row to ensure optimal growth. They discuss questions such as, "How many seeds do we put in each row?" and "How many rows can we fit in our space?" An aerial view of the garden after planting reveals a complex, yet regular and well thought out, plan. All created by the children.

Children are owners of the school garden, and they take their responsibility to care for it seriously. Although much support and collaboration among families, staff, and community members are needed to maintain the garden, children actively engage in gardening throughout the year.

After planting the seeds, they visit the garden on a daily basis to see how much the plants have grown. They discuss and document what happened overnight, and whether the plants need water, weeding, or trimming. Through these care activities, children develop a strong sense of responsibility and ownership. Over time, the data that the children collect reveal even more growing patterns. Charts and graphs can be developed to give visual representations of the growth ratios over time. Could there be a connection to the golden ratio?

As trees and flowers start budding and blossoming in spring/summer, the garden transforms into a space for children's observation, imagination, and wonder. Each plant and flower is unique in color, shape, texture, and scent. And yet there are similarities as well, and many of these similarities relate to growing patterns. Remarkably, the number of petals on many flowers corresponds to the Fibonacci sequence: buttercups have 5 petals, lilies and irises have 3 petals, some delphiniums have 8 petals, corn marigolds have 13 petals, some asters have 21 petals, and daisies can be found with 34, 55, or even 89 petals.

The garden constantly changes and evolves with time and weather. Growth in the garden is visible and tangible. As they observe and work in the garden, children feel a sense of vitality and energy as well as a sense of gentleness and serenity. Within a garden, children feel relaxed and calm. Even children with learning difficulties feel safe and free of any pressure; this helps them focus better and behave more appropriately. The beauty to be found in a garden inspires children to draw/paint, make poems, express their artistic sense through dance or movement, or simply enjoy being in nature.[6]

"The Mystery of Newspapers and Corn"

One day, the children found a mystery: many pieces of newspapers were blown all over the garden. As they picked up the newspapers, they made several observations:

"Look, yellow silk! Someone's been peeling corn."
"There's corn all over the place."
"There's more. Look, look, look! We have a mystery."
"There's no tracks anywhere. What do you think left all this newspaper mess?"

After coming back to the classroom, the children discussed what might have happened to the garden and decided to investigate. As detectives, they went out to the garden and used magnifying glasses to find clues and thoroughly check for any animal tracks. They couldn't find any tracks, but many corn plants were torn to shreds and eaten off the cob.

Similar incidents happened a couple of more times, which led the children to theorize about possible predators in the garden and discuss ways to protect the garden against the mystery animal:

"How can we keep our garden safe?"
"How can we be kind to the plants, so they won't get broken and die?"
"What would be the plants that deer or groundhogs won't eat?"

In the discussion about how to keep the garden safe, the children suggested several constructive solutions. For example, children suggested a net to keep groundhogs out of the garden, which was installed later by adults. They also suggested installing a new sign on the gate and creating a mock garden that might trick the groundhogs into leaving the real garden alone. Through such experiences, children become keen observers, critical thinkers, creative problem-solvers, and collaborators.

Even these aspects of the garden are related to Fibonacci and the golden ratio. Many mathematicians theorize that the human sense of beauty is influenced by regular patterns of symmetry. According to Adrian Bejan, professor of mechanical engineering at Duke University, the human eye is capable of interpreting an image featuring the golden ratio faster than any other. Whether intentional or not, the ratio represents the best proportions to transfer to the human brain.[7]

Summer: The Garden in Motion

In the children's garden, teachers do not dominate the discussion or make judgments about the children's plans and ideas. Instead, they are facilitators who learn new things along with children. Subsequently, children are empowered and willing to participate in the inquiry process in the garden, where opportunities for observation, experimentation, and exploration are abundant. The teacher is a partner in the exploration, investigation, and learning.

In the summer, plants and vegetables may be damaged or harmed by unwelcome visitors, such as tomato grubs, deer, groundhogs, or rabbits. This can lead to another interesting use of patterns. Observing paw print patterns, patterns of destruction such as "this animal only eats tomatoes," and patterns of movement can lead to some interesting problem-solving activities in which the children discuss and develop ingenious ways to figure out what is happening to their garden and prevent the problems. The patterns they observe in the garden contribute to an adventurous project, in which children excitedly seek creative solutions as investigators and gatekeepers for the garden.

Ways to Facilitate Children's Imaginative Thinking

A garden stimulates children's wonder, curiosity, and imagination. In the garden, children can become "fairies," "parsley monsters," "gardening superheroes," "ghosts," or little bugs and insects sitting inside flowers. They also pretend that nature itself is something else; for example, tall flowers become "skyscrapers" and they are superheroes who help people out among the skyscrapers. They make up imaginary stories about monsters and dragons that exist in the garden while engaging in a chase game. They pretend that the garden is a campfire and they "roast marshmallows" on bamboo sticks.

Even though nature itself creates a fabulous atmosphere wherein children can become anything they want, concrete props and materials are wonderful tools to help them imagine beyond their present time and place. For example, small fairy figurines, a wood fairy house, a clay pot man, a flower lady, and/or a scarecrow can help children feel more welcomed in the garden and make a more friendly connection to it. Children treat these "people" as friends, siblings, or monsters that come alive. They care for those "people" in the garden, talking to them and creating their own stories about them. Children can make their own props, such as a scarecrow or a flowerpot lady. The garden becomes an extended space where children create their own world to care for with the full use of their imaginations.

Late Summer Into Autumn: A Celebration and Time for Bed

In late August, the children plan a garden party for families and community members. They invite the president of the university, the mayor of Athens, deans and faculty from the university, and anyone else who would like to celebrate their work on the garden. The children plan and prepare food from the garden's bounty: lavender cookies with fresh grown lavender, fresh salsa, pies, casseroles, zucchini bread, and, of course, ice cream. As children cut the vegetables, fruits, and berries, the inner structures of their bounty offer a great opportunity for comparisons and pattern recognition. These patterns are more than just beautiful, they are based on complex mathematical concepts that are again related to our old friend Fibonacci.

The garden continues to produce zucchini, pumpkins, and even tomatoes well into September, but at some point in mid-October the time comes to put the garden to sleep for the winter. Drying corn stalks and pumpkins become great October decorations for the school and classrooms. However, children learn that pumpkins can offer much more! Pumpkin pies, pumpkin cookies, pumpkin bread, pumpkin muffins, pumpkin soup, and roasted pumpkin seeds are just some of the many ways children use this orange wonder. And, of course, they love to carve and decorate their pumpkins to make jack-o'-lanterns.

Conclusion

A school garden offers a year-round investigation of patterns. It gives students the opportunity to observe the changes that take place through the entire seasonal cycle. From seed to first bud to mature plant, patterns are visible in all aspects of the natural world and children can be involved in every part of the process.

Notes:

[1] Kumari, K. M. (2016). Expression of Fibonacci sequences in plants and animals. *Bulletin of Mathematics and Statistics Research, 1*(S1.2016), 27-35.

[2] Farenga, S., Joyce, B. A., & Ness, D. (2001). The science and mathematics of nature. *Science Scope, 25*(2), 10-13.

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[4] Omidvar, N., Wright, T., Beazley, K., & Seguin, D. (2019). Examining children's indoor and outdoor nature exposures and nature-related pedagogic approaches of teachers at two Reggio-Emilia preschools in Halifax, Canada. *Journal of Education for Sustainable Development, 13*(2), 215-241.

[5] https://telluridemagazine.com/why-are-snowflakes-beautiful

[6] McDowell, J. C. (2013). Arts in the garden. *Young Children, 24*(4), 30-32

[7] Carson, B. (2010, January 4). Why do people like the golden ratio? *The Atlantic.*

Related Children's Book About **Mathematics**

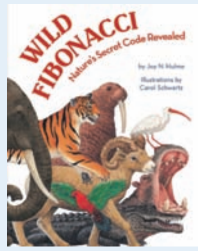
Growing Patterns: Fibonacci Numbers in Nature

Sarah C. Campbell

This ALSC Notable Children's Book uses nature photography to introduce the Fibonacci sequence, demonstrating connections between mathematics and the natural world. The pattern appears in the disk of a sunflower, the skin of a pineapple, and the spiral of a nautilus shell. The book brings math alive, celebrates science, and will inspire kids to see nature through new eyes.

Wild Fibonacci: Nature's Secret Code Revealed

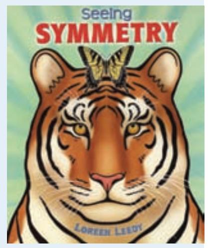
Joy N. Hulme



The Fibonacci sequence is part of a code that can be found everywhere in nature. Count the petals on a flower or the peas in a peapod. The numbers are all part of the Fibonacci sequence. In *Wild Fibonacci,* readers will discover this mysterious code in a special shape called an equiangular spiral. This spiral appears throughout the natural world: a sundial shell curves to fit the spiral, as does a parrot's beak, a hawk's talon, a ram's horn, and even human teeth. Joy Hulme provides a clear and accessible introduction to the Fibonacci sequence and its presence in the animal world.

Seeing Symmetry

Loreen Leedy



This book is aligned with the Common Core State Standards for 4th-grade mathematics in geometry: (4.G.3). Once you start looking, you can find symmetry all around you. Symmetry is when one shape looks the same if you flip, slide, or turn it. It's in words and even letters. It's in both nature and man-made things. In fact, art, design, decoration, and architecture are full of it. This clear and concise book explains different types of symmetry and shows you how to make your own symmetrical masterpieces. Notes and glossary are included.

Swirl by Swirl: Spirals in Nature

Joyce Sidman

A Caldecott medalist and a Newbery Honor-winning poet celebrate the beauty and value of spirals. What makes the tiny snail shell so beautiful? Why does that shape occur in nature over and over again—in rushing rivers, in a flower bud, even inside your ear? With simplicity and grace, Joyce Sidman's poetry paired with Beth Krommes's scratchboard illustrations not only reveal the many spirals in nature—from fiddleheads to elephant tusks, from crashing waves to spiraling galaxies—but also celebrate the beauty and usefulness of this fascinating shape.