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A Closer Look at Flowers: Exploring Structure and Function in Science and Art

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A Closer Look at Flowers: Exploring Structure and Function in Science and Art

A Closer Look at Flowers

Exploring Structure and Function in Science and Art

BY LAURA ROBERTSON

Flowers are one of the more familiar aspects of nature, appreciated for both their beauty and fragrance. However, in school settings, students need to take a closer look to appreciate the anatomy of a flower and understand its role in the life cycle of a plant. I integrate artistic design into my unit on flowers to add another lens through which students can evaluate the specialized structures and organization of flowering plants.

The 5E model (Bybee et al. 2006) was used to structure the lessons of the unit, providing opportunities for students to alternate between hands-on and minds-on activities. Each lesson begins and ends with one or more focus questions to engage students in critical thinking and to scaffold the culminating arguments that students will create.

Preparation and materials list

Two to three weeks prior to the unit, make calls to local grocery stores and floral shops to locate possible community partners willing to supply free flowers. Ask the stores to save flowers that are a little past date and would no longer be sold. The best flowers for the lab are lilies and *Alstomeria*, because they have large, easily recognizable reproductive structures; each student needs at least one of these flowers. It is helpful if the flowers differ in their physical characteristics, rather than being identical. Other types of flowers are helpful to include so students can see several flower arrangements such as tulips, begonias, and daisies. Students will also need hand lenses, rulers, and dissection probes (toothpicks are an inexpensive alternative).

CONTENT AREA

Life science

GRADE LEVEL

7

BIG IDEA/UNIT

Sexual reproduction in flowering plants

ESSENTIAL PRE-EXISTING KNOWLEDGE

Plants have internal and external structures that function to support survival, growth, behavior, and reproduction [4-LS1-1].

TIME REQUIRED

Six [45–60 minute] class periods

COST

$20 or less in consumable flowers and toothpicks; $15 for a reusable class set of hand lenses.

Addressing allergy concerns

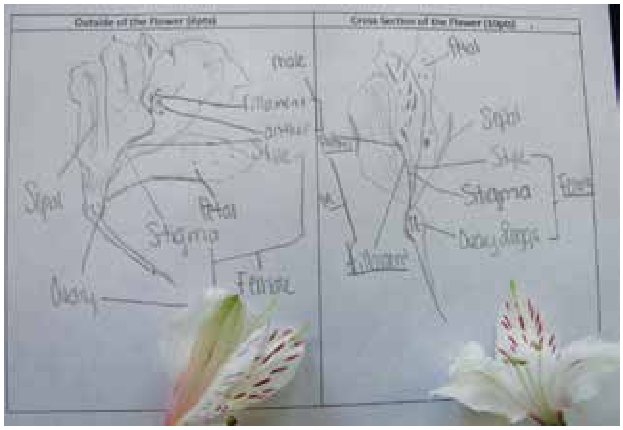
The day before the lab dissection, students are given the optional homework of finding and bringing in a flower. It is important to give students an allergy alert about the work they will be doing the next day, so that they can take allergy medication if they need it. During the lab, the windows and doors should be kept open to help ventilate the room. Students should be instructed not to touch their eyes, or they can wear goggles for additional protection. After the lab, wipe all tables to remove pollen.

Day 1: Engage and explore flower structure through observation and dissection

As students enter the classroom, the flower specimens and dissection tools are displayed at the front of the room to build excitement. The lesson begins with two focus questions and a video to engage students' prior knowledge: "In what context have you heard the phrase 'structure and function' used? How does the concept of structure and function relate to flowers?" The four-minute video clip "The Beauty of Pollination" is available free online from the film *Wings of Life* (see Disneynature in Resources). After the video, students are given a few minutes to think, pair, and share their answers to the focus questions, but a whole-class discussion is saved until the end of the lesson.

Because the focus of the lab is on exploration and observation, the investigation has a loose structure; the procedure is short and not very in-depth (see Figure 1). Students are encouraged to observe and dissect multiple flowers, but they are only required to record detailed observations for one flower, *Alstomeria,* or a lily. To provide a scaffold for students' sketches and observations, I share with them the work of a local artist, Suzanne Stryk, who uses detailed field notes to create her paintings and drawings. The book *Keeping an Eye on Things: Paintings and Drawings of Suzanne Stryk* (2009) includes pages from her sketchbook, which I project on a screen for all to see as I circulate among students. The artist and biology professor J. M. Landin has similar work available online (see Red Newt Gallery in Resources).

FIGURE 1: Detailed drawings of the outside and the cross section of the flower



Students have two goals during the lab. First, each student needs to make detailed drawings of the outside and the cross section of the flower (see Figure 1). Prior to handing out the flowers, I show an image of a flower cross section and demonstrate to students how to use their fingernails to make a cross section through the base of the flower to expose the pistil and stamen. A sharper tool such as a scalpel or razor blade could be used, but I find that fingernails are quick, safe, and effective. students are encouraged to use their textbooks or other reference materials (see *A field guide to wildflowers* by R.T. Peterson in Resources) while drawing and labeling, as these materials help students identify more structures of the flower and improve the quality of their drawings. Vocabulary is not introduced prior to the lesson; rather, students encounter the terms during the lab as they make observations and reference their resources. Second, students must create a list of qualitative and quantitative observations about the flower, such as color, size, scent, markings, and shape. It is important for students to produce high-quality work, because their drawings and observations will be used for the scientific practice of Analyzing and Interpreting Data in future lessons.

Although simple in its setup and execution, this lab is truly engaging and exciting for students. Students become engrossed in scientific observation and make frequent exclamations of discovery once they begin. The atmosphere is contagious! In addition to students' individual flowers, it is helpful to provide small groups of students with a variety of flowers, such as a lily, a tulip, and a daisy. This encourages careful comparisons and generates questions about the function of different structures and why structures are sometimes missing or arranged differently. For example, the petals of the tulip curve up and around the pistil and stamen, protecting the center of the flower. A daisy is actually composed of many small flowers; disc flowers make up the center of the flowering head, and ray flowers make up the outer portion. Begonias have separate male and female flowers. Although the number, size, and arrangement of flowers can vary widely, all of the flowers have the same function: to help the plant reproduce. At the close of the lesson, the focus questions from the beginning of the lesson are revisited. Students share with the class their observations and ideas about how structure and function relate to flowers. Students are prompted to include details from their flowers that were new or unexpected.

Day 2: Explain the crosscutting concept of Structure and Function in flowers

After the exciting dissection lab, the next day students connect the details of flower structures to their reproductive functions. The class begins with a new focus question that builds on the previous day: "How are flowers organized into specialized structures and what are their functions?" I draw a large flower on the board and label the parts and their functions with careful and repeated explanation of how the shape of an object relates to the job it performs. For example, the petals protect the pistil and stamen in the center of the flower and are often brightly colored to attract pollinators. This also reviews the vocabulary introduced during the Explore lab from the day before and ensures that all students have a complete list of the structures they are responsible for knowing (i.e., sepal, petal, pistil, stigma, style, ovary, ovule, stamen, anther, pollen, and filament). Students copy the drawing and notes into their notebooks to have as a reference.

In addition to emphasizing structure and function, I also take time to highlight similar words, such as stigma, style, and stamen, and ways to remember them. Memory tools can help students keep these s-words separate. The phrase "sticky stigma" reminds students that pollen lands there to start fertilization. The image of a "stylish" model helps differentiate the female part of the flower called the "style." The name of the male reproductive organ, *stamen*, has the word "men" in it. Summary handouts of flower structure can be used to supplement class notes or as informational texts in which students locate the functions of each part of the flower (see The Biology Corner in Resources).

Following the summary of flower anatomy, the class returns to the focus question. Time is provided for students to use the scientific practice of Constructing Explanations. Each student writes a short explanation for how the shape of a particular flower structure helps it accomplish its function. These explanations can be one or two sentences long. Students cite empirical evidence in the form of observations from the lab on the previous day to support their reasoning. For example, a student might state that they felt the sticky top of the stigma, which helps the stigma to catch pollen that lands on it. To reinforce the crosscutting concept of Structure and Function, students can underline the structure and circle the function in their arguments. Students then share their explanations in small groups or with the whole class. All explanations should be evaluated by other members of the class to ensure that they include empirical evidence from the lab and are not simply restating information from class notes.

Day 3: Explain the process of pollination

On the third day, the focus is on the process of pollination. Students now have experience dissecting flowers and identifying the functions of specific structures. This day covers the mutualistic relationship between flowering plants and their pollinators, and it begins with a new focus question: "How do specialized plant structures increase the probability of successful reproduction?" The whole-class discussion covers the primary types of pollinators, their characteristics, and the characteristics of the flowers that they pollinate. Typically, the list of pollinators includes insects (with a focus on bees), birds, mammals, wind, and water (see Nature's Partners in Resources). Throughout the class period, students are shown images of different flowers and asked questions such as, "What do you notice about these flowers that might attract a pollinator?" and "Why would a flower pollinated by the wind have large amounts of pollen?" Again, students take notes in their notebooks for reference during future activities.

After students have a base of knowledge about types of pollinators and associated flower designs, the next step is a free, interactive game, "Pick the Pollinator" (see Resources). The game includes pictures and descriptions of flowers with a list of possible pollinators. Students use the clues about the flower's structure to select the type of pollinator that visits it. Many of the flowers and pollinators are unique specimens with highly evolved mutualistic relationships.

At this point, the concept of probability relative to pollination can be introduced, addressing the crosscutting concept of Cause and Effect. From my experience, this is one of the more challenging concepts for students. They have difficulty understanding that pollinators are not consciously helping the plants, and that chance is involved with each brush of the pollinator's body against a stigma. I have found readings of informational texts helpful in addressing this relationship and have used a reading from *Honey Bees: Letters from the Hive* (Buchmann 2010), which reviews the methods that flowers use to attract pollinators and describes the concept of pollination as "a lucky accident."

The closing activity requires students to apply knowledge through the science practices of Analyzing and Interpreting Data and Engaging in Argument from Evidence. Students review their data from the flower dissection on the first day to infer the most likely type of pollinator for their flowers. In response to the focus question, students write a one-paragraph argument based on evidence from their lab data and notes in their notebooks. (Students should make their arguments with the assumption that their flowers are pollinated naturally.) After students write their paragraphs, they model scientific-community discussions by sharing arguments in small groups or with the whole class. Within their writing and discussions, students should address the idea that the characteristics of the flower and behavior of the pollinators increase the probability of successful reproduction rather than ensure it with each visit to a flower. I listen for students to use phrases such as "the pollen *might* brush against the stigma" or "pollination occurs *if* the insect visits another flower of the same type" to demonstrate their understanding that chance is involved in the process of pollination. Unless students have conducted outside research or possess prior knowledge about the flowers used during the dissection, the pollinators for each type of flower are unknown; therefore, students must carefully present their reasoning and respond to the comments of others. At this time, the concept of a counterargument can be introduced to students as an alternative view or interpretation of data. Encourage students to critically evaluate the reasoning and lines of evidence of their claims and those of their peers to build a collaborative spirit of searching for the best arguments.

Days 4 and 5: Elaborate with structure and function in art

On the fourth day, students are ready to consider the crosscutting concept of Structure and Function from a new perspective, the principles of artistic design. Artists use particular techniques within their works (structure) to evoke a response (function) from the viewer. The lesson does not require extensive background knowledge in art or art education; a quick search on the internet will explain the basic ideas and reveal additional artworks that could be used with students (see Principles of Design in Resources). Another approach would be to collaborate with the school art teacher, in which case some of the content and time for students to work on their projects could be shared.

To begin the activity, the focus question of the day is: "How is the concept of structure and function in art similar to and different from the concept in flowers?" The examples provided highlight six principles (or *elements*) of design: balance, contrast, emphasis, movement, proportion, and repetition (see Figure 2). Students need to copy into their notebooks the six principles of design to use as a word bank, and they need a brief introduction to each of the concepts. Students are then shown six works of art (see Figure 2), and for each of the works, they pick the element of design that stands out the most to them. I encourage students to use each of the principles only once and to make their selections without discussing answers with their classmates.

After students have made their selections, we go back through the images of art, and students share the principles that stood out to them. All of the principles are present in each of the artworks, so any student answer is accepted as long as the student supports the claim with evidence from the artwork. Accompanying each piece of artwork is a complementary example from nature (see Figure 2). Students typically express surprise that the principles of art show up in flowers and often have a similar purpose in the plant–pollinator relationship. For balance, the image shows the radial symmetry of a flower. For contrast and emphasis, the flowers have strikingly different colors on petals and the center of the plant. Images of flowers under UV light show contrast that is visible to insect pollinators. Motion is best represented with nectar guides, which move pollinators (and the eye) toward the center of the flower. For proportion, the very large sunflower is an example of the great size of some flowers. For repetition, images show massive numbers of flowers on a plant, making the plant easier for pollinators to find. After the art and flower examples, students return to the focus question and work in small groups to compare and contrast structure and function in art and flowers. One significant difference between structure and function in art and flowers is that the concept is used intentionally by artists but is the chance result of millions of years of evolution in flowering plants. Students can create Venn diagrams or write paragraphs to summarize their thinking.

At the end of the fourth day, it is time to introduce the culminating Flower Discovery and Argumentation Project (Figure 3). In this project, students imagine that they are scientists who have discovered new flowering plants but have not yet observed the pollinators. Each student must provide a labeled drawing of his or her "discovery," similar to the images produced at the beginning of the unit in the dissection lab, and write an argument for the most likely plant–pollinator relationship based on the flower's structure. Within their arguments, students must address how the structure and function of the flower help attract pollinators and increase the probability of successful reproduction. Students will present their newly discovered flowers and their arguments to their classmates in a simulated scientific conference on the last day of the unit.

This is the longest argument that students will create during the unit. Each of the previous lessons has included one or more science practices to help prepare students for creating a cohesive argument supported by multiple lines of evidence. In an essay that is approximately three to five paragraphs, students have the space to make a claim, cite supporting evidence, address counterclaims, and make concluding remarks. In the counterclaims section of the essay, students should ad-

FIGURE 2: Principles of artistic design with examples from art and nature

Principle of design	Example from art	Example from nature
Movement: how the eye moves across the artwork	van Gogh, V. 1889. Starry night (painting). *http://mo.ma/1mmuiHO*	Bearded iris with nectar guides 
Balance: color, texture, and weight are evenly distributed; in radial symmetry, features surround a center point	Albers, J. 1953. Homage to the square: "Ascending" (painting). *http://bit.ly/29OxyKJ.*	Passion flower 
Emphasis: part of the artwork stands out and catches the viewer's eye	San Vitale Mosaics (c. 550 A.D.). Empress Theodora and attendants (mosaic). *http://bit.ly/2ac6pDX.*	Hibiscus 
Proportion: relative sizes and amounts of parts of the composition	Oldenburg, C. 1976. Spoon and cherry (sculpture). *http://bit.ly/1fefqN8.*	Sunflower 
Contrast: opposites in color or shape create visual interest	Orozco, J.C. 1931. Zapatista (painting). *http://mo.ma/2a0lpph.*	Lily 
Repetition: the repeated use of an image or design element throughout an artwork to create unity	Warhol, A. 1962. Campbell's soup cans (painting) *http://mo.ma/29NomXT.*	Hydrangea 

FIGURE 3: Flower discovery and argumentation projects

Task: Imagine you are a botanist who has recently discovered a new species of flowering plant. You have spent time in the field making careful observations of the flowers of the plant; however, you have not yet observed the pollinator. You are going to share your discovery at a scientific conference of your peers and make an argument for the type of pollinator that you predict is attracted to this new flower. Prepare a detailed, labeled drawing showing the unique structures of the flower and a written argument for the type of pollinator that visits the flower.

Things to include in your drawing:

1. Label the parts of the flower (i.e., petals, pistil, stigma, style, ovary, eggs, stamen, anther, pollen, and filament).
2. Show the physical structures of the flower that might attract a pollinator. Include at least three of the following:
   - color
   - markings
   - scent
   - shape
   - size
   - blooming period
3. Describe the predicted pollinator.
   - Why is it attracted to the flower?
   - Why does it visit the flower?
   - How does it transfer pollen?

Things to include in your argument:

1. Organization
   a. Introduction: State the type of predicted pollinator.
   b. Reasoning: Support your argument with evidence from the drawing. Give at least three specific details about how structure and function of the flower help draw the pollinator and increase the probability of successful reproduction.
   c. Counterarguments: State at least one example of a different viewpoint regarding the type of pollinator and then refute (disprove) this view.
   d. Conclusion: Restate your argument and discuss future work that could support your argument.
2. Your argument should be three to five paragraphs long and carefully edited for grammar, spelling, punctuation, and sentence structure.

dress at least one alternative interpretation of the set of flower characteristics.

It is necessary to provide students with class time to brainstorm ideas and begin work on their projects. While students work on their drawings, I conduct a formative assessment by checking with each student about his or her idea and probe for deeper explanations about the planned flower characteristics and the relationship between the plant and pollinator. Students benefit from the opportunity to talk through their thinking, and the process often sparks new ideas. Students usually focus on a pollinator visiting one specific flower, an issue that tends to occurr during the activity. Students forget or do not realize the importance of the pollinator visiting several flowers and transferring pollen from one flower to another on different plants. The formative assessment and resulting feedback give students an opportunity to refine their thinking prior to finalizing and presenting their projects to the class. Depending on time available, this classwork may extend over two or more days in order to meet with each student and to provide students with ample time to create their drawings and arguments.

Day 6: Elaborate and evaluate scientific arguments of flower–pollinator relationships

The last day in the integrated unit ties together material from each of the previous days with a final focus question: "Why do scientists engage in arguments based on evidence?" Arrange the classroom to simulate a conference setting, with a podium for presenters. Students share their drawings and refer to them while making their arguments. They must explicitly address the structure and function of the flower and explain the inferred relationship between the plant and pollinator. The presentations are short (lasting three to five minutes per student), but time is reserved for rich discussions of each "new discovery." To reinforce the culture of scientific discourse, encourage students in the audience to note exceptional aspects of the flower, ask clarifying questions of the presenter, and suggest alternative explanations. The scientific conference concludes with a discussion of the focus question and associated scientific practices addressed in the unit. How do the practices work together? What is the value of having multiple lines of evidence? How does argument strengthen scientific explanations? How can argument be used as a form of collaboration? After student presentations end, displaying the projects in the classroom or hallway simulates a conference poster session and allows students to continue the conversation.

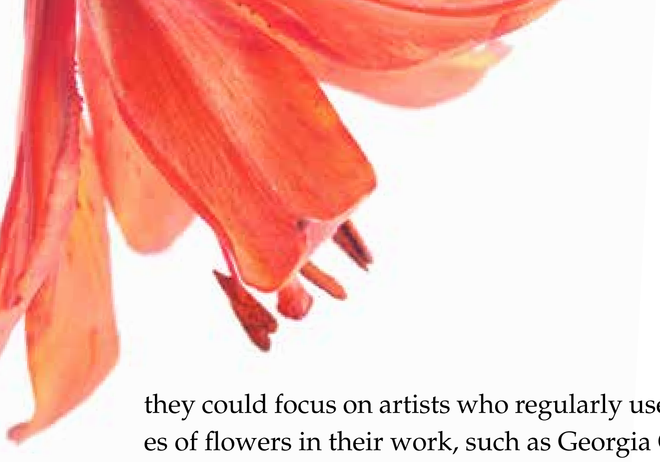
Differentiated instruction

The vocabulary-heavy nature of the anatomy content can be problematic for ESL students. Provide lists and definitions of terms, informational texts, and reference materials in students' native languages. ESL students may benefit from the opportunity to practice their oral presentations with the teacher or a peer prior to the scientific conference; the conference could also be altered to allow all students to present in small groups rather than to the whole class. ESL students and students with reading or writing disabilities may struggle with the literacy components of the lesson. Provide leveled texts for students with reading disabilities. Writing assignments can be modified without altering the performance expectations of students. For example, students may prepare shortened written arguments, focus on oral presentations, or dictate their thoughts to a scribe. Students could also be allowed to revise and resubmit their arguments as needed.

Extension ideas and conclusion

The unit as presented in this article represents the shortest possible sequence and pacing of the material; however, there are multiple ways to extend the unit if time allows, incorporating additional science, art, or literacy content. To extend the science content of the unit, additional lessons could address honeybees and colony collapse, food production, and native wildflowers. The informational text used on day three, *Honey Bees: Letters from the Hive* (Buchmann 2010), is a chapter book containing details about bee pollination, honey production, and the link between humans and bees at a reading level accessible to middle school students. The text *The Hive Detectives: Chronicle of a Honey Bee Catastrophe* (Burns 2010) details the unfolding story of colony collapse disorder in honeybees from the vantage point of beekeepers and scientists. It includes colorful pictures and a suspenseful storyline appropriate for middle grade students. Mobile applications with a game-like structure are also available to help students understand the role of pollination in food production (see Happy Orchard and Pollinate 2 Plate in Resources). Another extension idea is to have students design their own version of "Pick the Pollinator" based on the wildflowers native to their region. Research could be completed online or using local field guides to wildflowers (see Discover Life, eNature, and Peterson and McKenny 1996 in Resources).

As mentioned previously, this unit is an excellent opportunity to collaborate with the school art teacher. With the support of the art teacher, students' drawings during the dissection lab and their final projects could benefit from the additional time and expertise of the art teacher. In the final projects, students could be required to use two or more of the principles of artistic design. Compositions of this nature would most likely require three to five days of class time. An alternative option is to incorporate art critiques into the day 4 lesson. Students could study works of art in a four-part critique process, which is essentially a detailed examination of the structure and function of the artwork and the artist–viewer relationship (see Four Step Art Critique in Resources). Students could study art with any subject matter, or



they could focus on artists who regularly used images of flowers in their work, such as Georgia O'Keefe.

The literacy component of this unit could be extended with the addition of informational texts, such as those mentioned previously, or lengthening any of the speaking and writing components present in each of the lessons. The diagrams and observational data collected during the dissection lab could be used to create a two-page magazine layout with text features such as diagrams, captions, keywords, and headings. On the days that students write short analyses and inferences, more time could be spent crafting the coherence, flow, and organization of the writing pieces. Likewise, more time could be dedicated to oral presentations by students as they make claims and support them with empirical evidence.

This integrated unit designed to address three-dimensional learning of the *Next Generation Science Standards* engages students in higher-order thinking and a real-world application of knowledge and science practices. The culminating scientific conference in which students present their claims, cite evidence, and address counterarguments is representative of authentic scientific discourse. The integrated approach to structure and function deepens students' understanding of the amazing and beautiful results of reproduction in flowering plants. ●

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RESOURCES

The Biology Corner: Flower structure and reproduction—*http://bit.ly/29NlLwY*

Discover Life—*http://bit.ly/29Yqob8*

Disneynature: *Wings of life—http://bit.ly/29TMH37*

eNature.com—*http://bit.ly/29Ow2It*

Four step art critique—*http://bit.ly/29Vb37h*

Happy Orchard app—*http://apple.co/2a0jBN9*

Nature's partners—Pollinators, plants, and you—*http://bit.ly/29TA2sW*

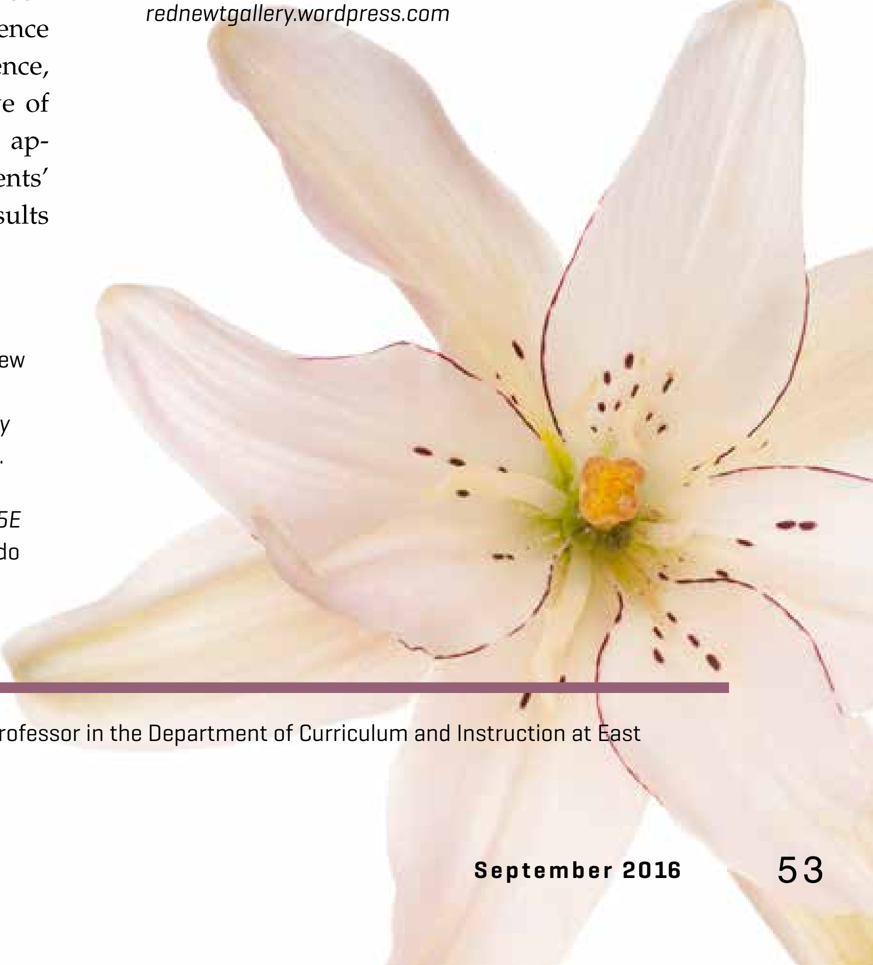
Peterson, R.T., and M. McKenny. 1996. *A field guide to wildflowers: Northeastern and North-central North America.* Boston: Houghton Mifflin.

Pick the pollinator—*http://to.pbs.org/1BsZtNf.*

Pollinate 2 Plate app—*http://apple.co/2a7EsL9*

Principles of design—*http://bit.ly/29Ow1EG*

Red newt gallery: Where art & biology collide—*https://rednewtgallery.wordpress.com*



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Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Standard

MS-LS1: From Molecules to Organisms: Structures and Processes

http://nextgenscience.org/ms-ls1-4-molecules-organisms-structures-and-processes

Performance Expectation

MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practice	
Analyzing and Interpreting Data	Students analyze their observations from the flower dissection lab, construct an explanation of the most likely type of pollinator, and engage in argument based on evidence (days 2 and 3)
Constructing Explanations and Designing Solutions	Students create oral and written explanations for the type of pollinator for a "newly discovered" flower. Students present their ideas at a scientific conference of their peers (days 4–6).
Disciplinary Core Idea	
LS1.B. Growth and Development of Organisms • Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized structures for reproduction.	Students dissect flowers to identify reproductive structures and their functions (day 1). Students write and present about a plant–pollinator relationship for reproduction in a flowering plant (days 4–6).
Crosscutting Concept	
Structure and Function	Students examine the role of structure and function in flowers and plant–pollinator relationships (days 2–4).
Cause and Effect	Students describe the impact of flower structure on the probability of successful reproduction through pollen transfer (days 3 and 6).

Connections to the *Common Core State Standards* (NGAC and CCSSO 2010)

ELA

RI.6.8: Trace and evaluate the argument and specific claims in a text, distinguishing between claims that are supported by reasons and evidence from claims that are not.

WHST.6-8.1: Write arguments focused on discipline content.