

Art + Science



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Introduction

From the moment of its creation, a work of art is always changing.

Artist Charles Ray was driving along the California coast when he noticed a decaying oak tree sunken into the meadow along the side of the road. Fascinated by the physical state of the dead tree— insect- and damp-ridden, clearly near the point of collapse—Ray brought the tree back to his studio and began a process of recreating it, eventually enlisting the help of craftsmen in Japan. While still appearing like the fragile shell of the original, the replica of the tree is just beginning a new life. *Hinoki*, the name of the artwork and the word for the Japanese cypress from which it is made, offers a reflection on our expectations for and experience of the changes that take place in a lifetime—our own and that of a work of art. Ray describes the predicted lifespan of *Hinoki*:

When I asked Mr. Mukoyoshi about the hinoki and how it would behave over time, he told me that the wood would be fine for four hundred years and then it would go into crisis; after two hundred years of splitting and cracking, it would then settle into a slow decline for another four hundred years. I realized then that the wood, like the original log, had a life of its own, and I was finally able to let my project go and hopefully breathe life into the world that surrounds it.

Ultimately, through its aging process, *Hinoki* takes on meaning as a work of art. We may never witness the dramatic physical transformations to the wood in our own lifetime—the large tree seems very stable to us as we view it in the museum gallery—yet we are reminded of the potential for change in the contrast of the features of the log’s decayed state with the newness of the Japanese cypress. We are also encouraged to reconsider our expectations for change, the scale or rate of which may be beyond our ability to experience.

Hinoki, through its physical materials and the ideas it evokes, invites broad connections between the disciplines of art and science while also providing a specific example of the undeniable role of change in works of art. Change—and its impact on stability—is not only a fundamental scientific concept but also a primary focus of the work of art conservators, who are trained as both artists and scientists.

The practice of conservators, the interdisciplinary nature of their work, and their attention to stability and change in art inspired the middle school Art + Science program at the Art Institute of Chicago.

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About Art + Science at the Art Institute of Chicago

Art + Science was developed by the Art Institute of Chicago to support dialogue and collaboration between art and science teachers at the middle school level, with the ultimate goal of inspiring art and science integration in the curriculum.

The program consists of two interconnected parts: this curriculum resource and a field trip to the museum, which features a gallery tour and studio art-making activity. The curriculum resource is intended to help teachers to prepare for and extend the field trip experience. Both the field trip and curriculum resource showcase and encourage interdisciplinary connections between art and science first on a broad level and then through the particular lens of stability and change.

Through the experiences included in this program, students will:

- Explore their perceptions of the practices of art and science
- Practice scientific and creative thinking through experiences with art objects by using their observation skills, reasoning skills, and imagining skills
- Examine the ways in which they possess skills valuable to both scientific and artistic thinking and practice
- Connect an understanding of art and science to their own lives
- Use the key concepts of stability and change as a means to explore the intersection of art and science*

**Stability and change are among the seven crosscutting concepts of the Next Generation Science Standards.*

As a result of participating in this program, students will:

- Begin to see the art in science and the science in art in real-world encounters
- Reflect on their self-identification (as an artist, a scientist, or both)
- Feel comfortable practicing scientific thinking in an art museum context

Using this Resource

This resource is intended for use in two primary ways: as support for teachers creating **Art + Science** explorations in the classroom, and as support for teachers planning to bring students to the Art Institute of Chicago for the **Art + Science** field trip experience. For those unable to visit the museum, the lesson plan for the field trip experience is included here and may be implemented in the classroom with digital or printed images of the works of art.

The activities in this resource are designed to promote collaboration between art and science teachers, allowing for students to explore connections between the disciplines in both classrooms, and, if possible, through a museum field trip. The activities are categorized as pre-museum visit, museum visit, and post-museum visit to provide a potential sequence for their use. However, individual activities can stand on their own or be combined with others in different ways according to the needs and interests of teachers. Used in combination, these activities will spark students' curiosity, extend understanding, and facilitate personal connections to the disciplines of art and science.

To promote teacher collaboration, the following strategies support an implementation of **Art + Science** activities in an integrated, interdisciplinary manner:

- Divide and conquer, with each teacher handling different activities in his or her respective classroom
- Repeat/reinforce an activity by doing it in both the science and art classroom
- Work together to enhance the activity by adding a specific art or science lens
- Block-schedule (if feasible) a period to provide more time for a combined art and science lesson/project

Specific works of art have been suggested for many of the activities. Images and links to information about these works are included at the end of this resource. Many other artworks from the Art Institute of Chicago or elsewhere may be equally as successful with these activities. Thus, teachers are encouraged to explore and utilize the works of art that best suit their curricular context. To further enhance an integrated art and science exploration with students beyond the scope of the activities found here, a list of related links to additional resources is included at the end of this resource.

A View from the Museum

Scientific thinking begins with curious observation—the posing of a question, perhaps the desire to solve a problem. To practice scientific thinking, one also uses the five senses, reasoning and imagining skills, and a variety of technical instruments and tools. Through close looking, experimentation, data collection, and analysis, scientists form hypotheses and (later) principles that inform our understanding of and engagement with the world. Artists use these same skills. They engage in detailed and thoughtful observation and description; they ask questions and experiment with materials and techniques; and they express new ideas and interpretations of the world around them.

Similarly, learning and thinking in an art museum are fueled in part by the same curious looking, experimentation, and interpretation as experienced in scientific practice. Viewers may not have access to formal instruments or possess prior knowledge when encountering a work of art; instead, they engage with objects by using their senses in conjunction with reasoning and imagining skills. They make observations, create connections, and test understanding.

Perhaps an art museum seems an unexpected setting for students to flex their scientific muscle. But in practice, an art museum is an ideal setting for exercising both artistic and scientific ways of thinking and being. It offers a demonstration of human capacity for curiosity and inventiveness—that of the artist as expressed in the work of art, which may in turn spark the curiosity and creativity of the visitor. Museum learners observe and then react in different ways to the content and provocations of an artist’s work: reflecting, debating, questioning, and creating.

Indeed science is all around us in an art museum. And science practice and knowledge has always been a part of art. Ancient Chinese artisans and Greek craftsmen perfected techniques for working in bronze and ceramics, undoubtedly experimenting with and coming to understand the properties of their materials as well as the chemical reactions of those materials under different conditions. Similarly, film photographers must be intimately aware of the chemical processes involved in developing photographic prints from negatives. Medieval and Renaissance European artists were also alchemists, mixing their own paints and fabric dyes from natural sources such as plants, minerals, and insects. In more modern times, the Impressionists were dedicated to the physics of color and light, attempting to recreate on canvas the effects of light in the natural world.

As a place dedicated to preserving the products of human creativity, the art museum is also a place where science is practiced in the form of conservation. Art conservators (professionals trained like “art surgeons,” who are in charge of examining and treating art) and conservation scientists (professionals trained as “art doctors,” who use scientific tools to diagnose the conditions, pathologies, materials, and making of art) are responsible for the ongoing care and treatment of works of art in the museum’s collection. These professionals work at the intersection of art and science. Their aim is to answer the following questions:

- How can we better understand an artist’s techniques and materials and the changes that have

happened or may happen to their artworks?

- How can we treat and stabilize fragile works of art, restoring both their visual and structural integrity?
- How can we prepare an object so that it can be safely viewed and enjoyed or travel to destinations near and far for exhibitions?

Art Conservation: A Lens for Investigating Stability and Change

Material transformation over time is an undeniable reality for any work of art. Such change results from interactions of the original components in the artist’s materials, because of aging or through exposure to light and other environmental conditions. Change is partly a natural evolution of the original materials: some pigments may fade the same way as our hair color eventually evolves to gray, and painted surfaces may develop a fine network of cracks (called craquelure) the same way we get fine lines and wrinkles over our own skin. Sometimes, external conditions effect change: natural or man-made disasters like floods, hurricanes, fire, or physical impacts may cause tears and holes. Human interventions may also cause change. In the past, restorations involving significant overpainting (i.e., painting with new materials in an area significantly exceeding the area of loss of original material), the use of solvents in treatments, or the sectioning of works of art to create smaller, more salable pieces have significantly altered works of art.

Conservators and conservation scientists must understand an artist’s materials and techniques to interpret his or her intent in creating a work of art. Working with historical documents, physical evidence, and advanced scientific tools, as well as curators (professionals trained as art historians who are in charge of collecting, interpreting, and displaying the art), the professionals involved in the conservation of works of art investigate and interpret the physical components of objects to better understand and care for them. Their specialized knowledge guides treatments designed to improve appearance and stability in works of art. Every treatment begins like a detective story; every object has a past waiting to be uncovered through close examination of its materials.

Thanks to science, engineering and digital technology, conservators have a broad range of tools for creating stable environments for works of art, for examining and analyzing works of art, and for documenting and sharing their own work. While conservation has always chosen treatment methods and materials based on their compatibility with an object and long-term stability and reversibility, the profession has seen an increasing trend toward treatments that involve minimal intervention. Now, conservators aim to alter the physical components of an artwork as little as possible, while assuring its stability and improving its appearance. Conservation scientists are able to analyze the art to look for signs of change, monitor the long-term effects of treatment and, increasingly, create computer models that can help us predict how art materials will behave in different environments and at time scales that cannot be reproduced in the lab. The Art Institute of Chicago controls the temperature and relative

humidity in the galleries and storage rooms and applies filters on light sources and windows to reduce light exposure and exclude harmful UV rays. All these aspects contribute to the long-term stability of works of art in the museum's care.

Art Conservation: A Case Study

A work of art is a physical object: like us, it has a history that leaves its marks. Following its creation, a work may be collected, stored, sold, loaned, and moved around. Over its lifetime, a work of art may also undergo several conservation treatments, including cleaning, consolidation (re-adhesion of fragile areas that have weakened or been damaged), restretching, or lining. Through any of these means, the work of art will be subject to external stresses that can create change in the chemistry and mechanical stability of the materials from which it is made.

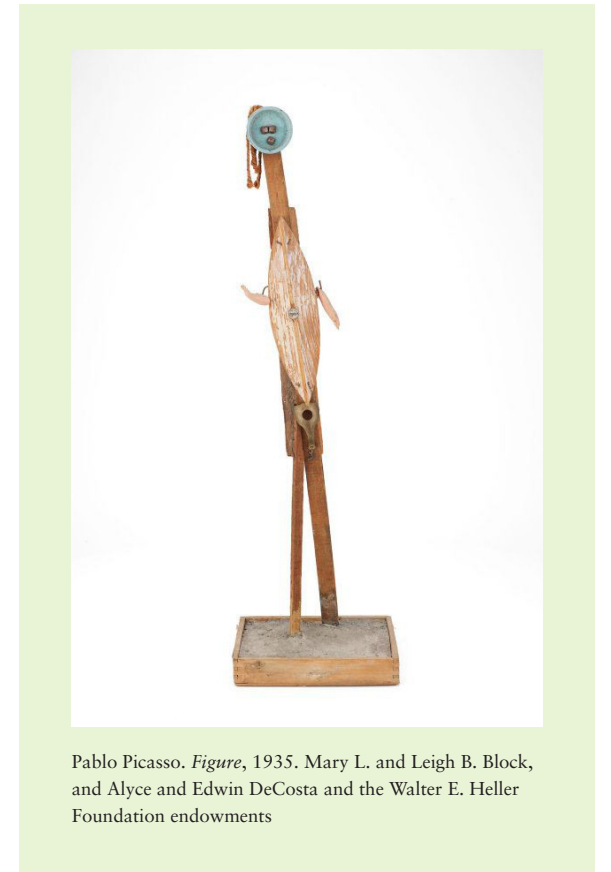
With funding from the National Science Foundation (NSF), Art Institute of Chicago conservation scientists and conservators collaborated with chemists and materials scientists at Northwestern University to understand how the materials that make up paint age and change over time. Using state-of-the-art scientific tools, scientists investigated questions such as:

- Has the paint system (in a given work of art) reached equilibrium? (Is it fully cured and stable)?
- If so, what changes might a conservator bring on in the paint when he or she uses solvents for cleaning?
- What changes might occur in the paint if the environmental conditions of the museum changed; for instance, if the temperature were no longer kept stable at 70°F but, in an effort by the museum to be more green, allowed seasonal fluctuations?

To begin to answer these questions, conservation scientists employed a combination of tools and experiments. First, they began with close observation of a work of art using specialized tools in order to determine the paint's composition and to look at the stiffness of the paint. Next, scientists used their knowledge to make new paints that resembled older paints and observed the behavior of the material in the laboratory in response to temperature and oxygen content of the air. They measured changes in the material's strength and weight as chemical reactions occurred.

Aging paint artificially and forcing change to occur quickly in the science lab is difficult. Changes in the material components of a work of art can take tens or even hundreds of years. In this project, scientists took a new approach that looks at systems and uses system models to make predictions. Working closely with museum scientists, a PhD candidate at Northwestern University used a computer program to simulate all the possible reactions that take place daily in paints in order to model how paint systems age naturally. This is a new way of looking at works of art and determining their ongoing care. If this new approach is successful, it will be a very powerful tool to predict the effects of man-made or environmental changes on actual paintings in the future.

This project was inspired by the 20th-century Spanish artist Pablo Picasso (1881–1973). Picasso experimented and pushed boundaries throughout his long artistic career. As early as 1912, he began using unconventional cans of ready-mix paint (called enamel), which was not designed for artists' use. In *The Red Armchair* (1931) (cover), Picasso used both traditional oil paint and this unconventional enamel; he even included the lid from a can of the enamel paint in his sculpture *Figure* (1935) (right). Picasso was the most influential of the early adopters of this brand new, unconventional medium. Today, we can buy ready-mix paint in a can at a local hardware store and quickly change the color of our house, our room, or a piece of furniture. One hundred years ago, it was a brand new and extraordinary idea that you could paint your house or your furniture yourself and without hiring a professional painter to mix the colors, or pigments, into the base paint. After all, artists had only been able to use ready-mix oil paint in collapsible metal tubes for less than a century before Picasso created *The Red Armchair*. The idea of using ready-mix house paint in works of art was radical.



Pablo Picasso. *Figure*, 1935. Mary L. and Leigh B. Block, and Alyce and Edwin DeCosta and the Walter E. Heller Foundation endowments

Picasso liked a specific type of enamel paint called Ripolin. The name originated from the combination of the inventor's surname, Carl Julius Ferdinand Riep, and lin, a shorthand for linseed oil, the binder that makes paint sticky and translucent. Ripolin boasted superior quality and attractive advertising. The brand was so famous that, much like the idea that "to google" something means to look something up online today, the verb "to ripolin" (or *ripoliner*, in French) meant to paint something with industrial enamels.

Ripolin paint came in a range of very bright colors and dried quickly into a hard glossy surface that didn't show the marks of the paintbrush, allowing free range to Picasso's creativity. It was also prone to happy accidents such as dramatic wrinkling and dripping, which can be seen in his famous work *Guernica* at the Reina Sofia Museum in Madrid, Spain.

Museum conservators and conservation scientists have spent many years determining the composition of Ripolin and the works of art in which Picasso used this paint. They even went on eBay to buy 100-year-old cans of paint in order to closely analyze its composition for reference. Now, through the NSF-funded research, the museum knows in which paintings Picasso used this new material and also how to best preserve them for the future. Because these paintings are fairly young (less than 100 years old), conservators today are likely the first to treat them and must be mindful of the changes that their actions and the museum environment can induce in these paints.

Student Experiences

The activities offered here are categorized as pre-museum visit, museum visit, and post-museum visit to provide a potential sequence for their use. However, individual activities can stand on their own or be combined with others in different ways according to the needs and interests of teachers.

Through encounters with these activities, students will:

- Explore their perceptions of the practices of art and science
- Practice scientific and creative thinking through experiences with art objects by using their observation skills, reasoning skills, and imagining skills
- Examine the ways in which they possess skills valuable to both scientific and artistic thinking and practice
- Connect an understanding of art and science to their own lives
- Use the key concepts of stability and change as a means to explore the intersection of art and science*

**Stability and change are among the seven crosscutting concepts of the Next Generation Science Standards.*

Pre-visit Activity 1A: Art + Science Provocations

Prior to your field trip, work with your collaborator (the art or science teacher at your school) to create some context for participating students. Work through the questions below to encourage students to explore their notions about the purpose and practices of science and art, the connections between the two disciplines, and their personal identity within these contexts.

Document student responses, either individually or in aggregate, so that you will have data for a comparison/contrast with their responses to the same questions post-visit. There are a number of ways to create this documentation and to illustrate differences and intersections, such as post-it notes on a visible wall in your classroom, individual or group Venn diagrams, and illustrated charts.

Discussion Prompts:

1. What is science about? Why do we practice science? Why do we learn about science?
2. What is art about? Why do we make art? Why do we learn about art?
3. What are the qualities of an artist? What do you think drives artists to make and share their art?
4. What are the qualities of a scientist? What do you think drives scientists to conduct and share their scientific investigations?
5. Where are art and science practiced?
6. How do your responses overlap so far?
7. In what other ways do you see art and science connected, especially in your personal life or in the world around you—in nature, your body, this classroom, or beyond? Where do you see art in science and/or science in art?

Pre-visit Activity 1B: We Are All Artists and Scientists.

Now that they have identified some shared characteristics between artists and scientists, encourage students to do some self-reflection and identify both the artist and scientist within themselves. Invite students to generate a self-portrait in writing or drawing in response to the prompts below.

1. What are you curious about? What are some big-picture questions about life (the human condition, history, the natural world, or other) that you are always exploring or hope to explore someday?
2. In what way(s) do you feel moved to create or make new things (a painting, a poem, a solution to a problem, other) in your life?
3. In what way(s) do you consider yourself an observer—someone who notices people, places, and objects around you? In what way(s) do you investigate or respond to those people, places, and objects after noticing them?
4. How do you go about finding answers to questions, locating information, learning something new, solving problems?
5. What kinds of tools do you use in your daily life (for work or personal activities)?
6. How does your sense of imagination express itself in your life?

Have students share their self-portraits and to create a written or spoken reflection on their identity with respect to art, science, or both.

Pre-visit Activity 2: Looking Two Ways

Have students consider examples of real people who exemplify the connections between art and science. For instance, there are artists who engage similar approaches as scientists as they create their artwork, and there are scientists who make artistic practices the subject of their investigation. Following are stories of two such cases.

Joseph Cornell: Case study of an artist

American artist Joseph Cornell is best known for his three-dimensional shadow boxes. A self-taught artist, Cornell assembled diverse objects and printed materials into boxes that encourage the viewer to make connections between the individual components. Cornell acquired many of the items for his montages from his daily life. He worked as a textile salesman, which took him frequently into downtown New York City. While in the city, he visited flea markets, bookstores, and souvenir shops during his business excursions, bringing home knick-knacks and other curiosities. He sorted his finds by themes such as the ballet, birds, maps, France, and astronomy, and then combined them in boxes of various shapes and sizes. Most of Cornell's boxes were completed in his home, at the kitchen table or in his basement art studio, at night or on the weekend.

On his trips into New York City, Cornell would also visit art galleries. One such visit in 1931 introduced him to the work of the Surrealists, a group of European artists who drew inspiration from such

ideas as chance, dreams, and the subconscious. These artists often experimented in collage, or the arrangement of paper and other flat materials on a flat surface, and assemblage, the arrangement of found objects or other materials in a three-dimensional work. The Surrealist works strongly influenced Cornell in his own art making; he even exhibited his assemblages in Surrealist exhibitions, although he never considered himself a Surrealist artists and preferred to explore art on his own.

In addition to his visits to flea markets, bookstores and art galleries, Cornell enjoyed visiting museums around New York City. He was particularly interested in the planetarium and natural history museum. The information and objects he encountered during those museum visits are often reflected in the themes he chose for his artworks.

Joseph Cornell acted on his curiosity—by collecting, investigating, and categorizing things he observed in the world around him. Look at some of Joseph Cornell’s boxes that are on display at the Art Institute of Chicago.* How does his work remind you of the connections between art and science? How does his work invite your curiosity and imagination?

**Note to teachers: One of Cornell’s boxes is included in this resource (see appendices).*

To view others, please visit collections page of the Art Institute of Chicago’s website: www.artic.edu.

Francesca Casadio: Case study of a scientist

“Growing up in Italy, art has always been around me and is one of my great passions.”

Francesca Casadio is the senior conservation scientist at the Art Institute of Chicago. Growing up, she visited art and museums in her native Italy, as well as in many other parts of the world. When she went to university to study chemistry, she knew that she was particularly interested in color and artists’ pigments. This focus led her eventually to her role as a scientist in an art museum.

As a scientist, when Casadio looks at an object in the museum, she thinks like a detective. She uses her observation skills and tries to find clues as to how the artwork was made. Artists always leave traces of their process at or below the surface that can be explored like a map in order to retrace their steps. Sometimes simple tools like our eyes and magnification provide a glimpse into an artist’s technique. At other times, very high tech instruments that use invisible and powerful energies like x-rays, ultraviolet (black light), laser light, and infrared (heat) allow us to go below the surface, revealing clues about what materials the artist used and if they have changed over time.

After conducting such observations, Casadio usually has new questions about the work of art, the artist, and his or her practice. To help her answer these questions, she documents her work in a lab notebook—just like artists who make sketches to work out a composition, detail, or idea. This way she can always trace her steps, or come up with a new path to answer her question if the first plan did not work out as she imagined.

To interpret the results of her scientific investigations, Casadio has to understand the context of the work of art: how the artists worked, how they painted, sculpted, assembled or otherwise fabricated their artwork. To do this means to take a larger look at the past, at the history of the object while it was in the museum’s care, and before it even entered the Art Institute, all the way down to the history of the artist who created the work. In a similar way, artists also often confront the past to find their distinctive voice in the present.

All this information may help answer the question: what could have changed the art since the time it left its maker’s hand? Casadio also has to think about the environment: how are the air, the pollutants, the light, the heat, and the humidity affecting the original materials of a work of art when it is not conserved in the controlled environment of a museum?

Through her work every day, Casadio sees how the practices of art and science are both inspiring expressions of human creativity, getting at the big questions of life with different tools perhaps, but surprisingly similar paths of thinking and doing. That’s why she thinks of herself as an artists’ scientist.

Who Else? Finding Other Examples

After reading about Joseph Cornell and Francesca Casadio, ask students to reflect on ways that each demonstrates connections between art and science. Explain that these examples are not unusual. Assign or ask students to identify other such artists and scientists (possibly one of each) and then have students conduct research to find out how that person embraced shared aspects of artistic and scientific thinking and approaches. Have students create illustrated reports of their findings and have them present the reports to the class and/or create an in-class exhibition of them.

Pre-visit Activity 3: Stability, Change, and Choice

In science, the concepts of stability and change are fundamental to our understanding of systems and the functioning of the world around us. They also can characterize the investigative process, as a scientist’s data may reinforce or suggest changes to an initial hypothesis and subsequent research. Similarly, stability and change also characterize the creative process of artists as they act on their curiosity and experiment with and respond to the materials, composition, and the subject matter of their art. This activity provides students with an opportunity to develop working or expanded definitions of stability and change, supporting further explorations of the intersection of art and science.

Review with students a list of topics covered (or to be covered) during their science curriculum over the course of the school year. Discuss the investigations unique to each topic and ask students to identify the ways in which stability and change factored into the methods and results of the investigation.

Now look at the example of an artist’s creative process. Henri Matisse worked on *Back* over the course of 23 years. With its various states, it is, as the artist’s daughter suggested in 1976, one sculpture that passed through several stages of evolution. After *Back (I)*, Matisse began each time with a new plaster cast of the previous state: the first would remain as the work we know today—*Back (I)*,

Back (II), and so on—while the second served as the base from which he would start his new explorations.

See the study of the sculptures in question by the Art Institute of Chicago’s Matisse research team at www.artic.edu/aic/exhibitions/matisse/backp0.html.

Inspired by the example of Matisse, prompt students to make two or three drawings of the same subject (chosen by teacher or student) using different artistic styles and/or materials. What elements of the subject stayed the same in each drawing? What elements changed? How does the illustration change with the different materials?

Have students select their favorite drawing and share why in small groups or a written essay. How do you, as an artist, decide what style or medium is best for representing a subject or idea? How can you connect this back to your understanding of the fundamental roles of stability and change in the scientist’s investigative process?

Art + Science Tour and Studio Experience

The Big Idea

Close and curious observation lie at the core of artistic and scientific thinking and practice. Artists and scientists alike look at the world around them, ask questions, and use their reasoning and imagining skills and the media and tools of their disciplines to respond to and interpret what they see. The Art + Science Tour and Studio engages students in thinking through the connections between artistic and scientific thinking and practice through experiences with original works of art in the museum. Students then have the opportunity to consider the connections between art and science through the lens of stability and change, key concepts in science learning and a condition that students experience both in their personal lives and within other disciplinary fields in school. With the Art + Science Tour and Studio, students connect a new understanding of this key concept and of the relationship of these areas of study to their own lives.

Note: The following outline describes the experience students will have on the Art Institute of Chicago’s Art + Science Tour and Studio, which includes a 90-minute museum tour with a docent, a volunteer museum educator, and one-hour studio experience. The works of art included in the outline are examples of those that students will discuss during the tour. Because the museum is a busy and ever-changing place, there is no guarantee that these specific works of art will be on view for all tours.

If a group is unable to visit the museum for the tour and studio program, the activities in this tour and studio outline can be carried on in the classroom using digital or printed reproductions of works of art. All selected works of art in the outline can be found online through the museum’s collection page: www.artic.edu/aic/collections/.

Field Investigation Guide: Both artists and scientists look closely and record their observations as they work. Students visiting the museum will be given a field investigation guide to use during their tour. A template for the guide is also included in this resource for teachers to use if they carry out the tour activities in the classroom.

Stop One: “I Can Add to That!”

On this stop, students play a game that helps to establish the **social learning atmosphere** of museum-based learning and warms up their looking skills. Students will sharpen the **close observation and describing skills**, which are critical skills in both artistic and scientific practices, and which underpin their subsequent engagement with works of art. This stop also introduces the ideas of **curiosity** and of using different **lenses** when looking at a work of art.



Berthe Morisot. *Woman in a Garden*, 1882–83.
A Millennium gift of Sara Lee Corporation, 1999.363



William Victor Higgins. *Spring Rains*, c. 1924. Friends of American Art Collection, 1924.18.

Basic Procedure:

1. Students look together silently for about a minute and then play a game that asks them to contribute observations to a group conversation. The only rule is that each student’s observation must build on the one before, using the phrase “I can add to that.”¹
2. Students look again and this time consider what the artist might have been curious about when making the work of art, both in terms of what is depicted and of the work of art as a material object itself, and what a scientist might be curious about in looking at the work of art. Students can discuss the similarities and differences between their ideas about the interests of artists and scientists.
3. Students then have the opportunity to use their field investigation guides to record the things about which they are curious, in the form of questions.

¹ “I Can Add to That” School and Teacher Program. © Museum of Contemporary Art Chicago

Stop Two: Many Ways of Looking

This stop focuses on further connections between artistic and scientific thinking and practice, in terms of making and recording observations, asking questions, and considering avenues to extend or respond to curiosity.



Wedding Ensemble for a Groom (Umyeni), 1950s. Thembu. Restricted gift of the Woman's Board of The Art Institute of Chicago; partial gift of Axis Gallery (Gary Van Wyk and Lisa Brittan), 1998.519



Crowned and Bejeweled Buddha Seated on an Elephant Throne, late 19th century. Burma (Myanmar). James W. and Marilyn Alsdorf Collection, 1983.979.

Basic Procedure:

1. Students look quietly and then each select a small portion of the object on which to focus their attention. The group is divided in half and then given the charge that half will record their observations through writing and half through sketching, using their field investigation guides.
2. Students then switch the mode of recording observations: if writing, they now draw and vice versa. As a group, students discuss what they observed, how they recorded their observations, and what changed in their observation when they switched modes.
3. Students then look again at the whole object and consider what their observations of the detail tell them about the entire work of art.
4. Students record the things about which they are curious and pair-and-share to discuss. As a group, students then discuss how one might go about answering those questions.

Stop Three: Considering a Scientific Concept—Stability and Change

This stop situates the exploration of the connections between art and science within the key concepts of stability and change (NGSS). Students use their **observation**, **reasoning**, and **imagining** skills to speculate about **change over time**.



War Shirt, 1830/40. Upper Missouri River Tribe. Frederick W. Renshaw, Ada Turnbull Hertle, and Curator's Discretionary funds; restricted gift of the Donnelley Foundation, Cynthia and Terry E. Perucca, and Mrs. Leonard S. Florsheim, Jr.; African and Amerindian Art Small Gifts Fund; Arnold Crane Endowment; African and Amerindian Art Purchase Fund; David Soltker and Irving Dobkin endowments, 2004.485.



Jean Baptiste Joseph Wicar. *Virgil Reading the "Aeneid" to Augustus, Octavia, and Livia*, 1790/93. Wirt D. Walker Fund, 1963.258.

Basic Procedure:

1. Students look closely at the work of art and discuss how artists use the elements of art (e.g. line, shape, color) and materials to express ideas.
2. Students then consider the work of art from the perspectives of stability and change, in terms of the composition (elements), the subject matter (what is depicted), and/or the material components. Students speculate about the meaning of the work of art, based on their observations.
3. Using their imaginations, students then further speculate about potential change in the work of art. The group is divided into three parts. One third of the group works together to determine what might happen in one minute. One third of the group works together to determine what might happen in one year. One third of the group works together to determine what might happen in 1000 years. Students may speculate both about the object itself (its material qualities) and about the subject matter (the things depicted within the work of art).
4. Students end by recording their thoughts, ideas, and questions in their field investigation guides.

Stop Four: Change in Thinking

On the last stop of the tour, students return to the work at which they began and revisit their initial ideas and questions. The emphasis of this discussion is to **reflect on change in personal orientation and thinking**, and to re-emphasize the learning at each of the major stops.

Basic Procedure:

1. Students look back to their initial questions to determine which are still relevant to them, what new questions arise as a result of having looked closely at other works of art, and what new observations they have as a result of having sharpened their looking skills.
2. Students then make personal connections to the key concepts of stability and change by envisioning moments in which they experienced either or both. Students record these ideas in writing and sketching.

Studio Activity

The focus of the studio component of the Art + Science museum experience is to allow students to translate their new-found ideas about close observation, recording observations, and stability and change as cross-cutting concepts into material form.

Materials: Assorted colored pencils, 4" x 4" white sheets of paper (20 per student) with holes punched in one corner of each piece

Students will be introduced to and then play a continuous game of telephone, using observing and drawing instead of listening and speaking. Arranged in a circular table formation, each student will begin by creating a drawing, with the subject matter suggested by the teacher. Then, in unison, each student will pass his or her drawing to the right. Students will look closely at the drawing they have received and be given a limited duration of time to reproduce it. This new drawing is stacked on top of the original and passed to the right again. Students look only at the top drawing they receive and attempt to render it in the given amount of time. This process of observing, drawing, and passing repeats until each pile of drawings circulates the room, having been reinterpreted/drawn by each student. Students will receive a full set of drawings with their own original at the bottom. Students then lay out their pile of drawings in order to reveal and discuss the transformative process of this activity. Teachers may provide ring clips to students to clip their collection of drawings together.

Post-visit Activity 1: Art + Science Provocations, Revisited

How did your students' perceptions of art and science—and of themselves as artists and scientists—change as a result of the field trip experience? Revisit the discussion prompts that you explored prior to the field trip and ask students to reflect on any change in beliefs or thoughts. Document your students' responses and compare and contrast them with the pre-visit responses. Again, an illustrated chart or another strategy could be used to visualize the discussion and exemplify art and science connections.

Discussion Prompts:

1. What is science about? Why do we practice science? Why do we learn about science?
2. What is art about? Why do we make art? Why do we learn about art?
3. What are the qualities of an artist? What do you think drives artists to make and share their art?
4. What are the qualities of a scientist? What do you think drives scientists to conduct and share their scientific investigations?
5. Where are art and science practiced?
6. How do your responses overlap so far?
7. In what ways do you see art and science connected, especially in your personal life or in the world around you (in nature, in your body, in this classroom, beyond)? Where do you see art in science and/or science in art?

Revisiting these prompts and identifying shifts or stasis in thinking offers a natural way to extend the on-site exploration of stability and change.

Post-visit Activity 2: Taking Note

For this activity, students will observe a familiar object while altering their perspective. By engaging in close looking, and experiencing an object through multiple lenses, students practice one of the shared ways of thinking of artists and scientists: curious observation.

Select an object for students to observe. Objects that feature variation in details, shape, and texture will provide the richest experience. Ask students to begin by viewing the object with the naked eye. They should record their observations and questions through both written and illustrated note taking. Next, ask students to view the object in a variety of new ways: using a handheld tool (e.g., a magnifying glass), changing the light, closing one eye, sitting down or standing up, looking at the backside, or another perspective that they choose on their own. Again, students should document their observations and questions through both written and illustrated note taking.

Ask students to reflect on their close looking in the following ways:

1. How does the appearance of your object differ when viewed by the naked eye versus with interventions? How would you describe what you saw at each stage in this activity? Did you make any new observations or questions?
2. What types of information can you get by looking at an object in different ways? Why would this be important to scientists? To artists?
3. Why is the act of note taking an important step in curious observation?

Post-visit Activity 3: Be an Artist. Be a Scientist. Be Curious.

“Be curious, I know I will forever be.”

—Stephen Hawking

“For wonder is the seed of all knowledge.”

—Francis Bacon

The most obvious and significant shared characteristic between artists and scientists is curiosity—a drive to ask questions, an inclination toward wonder, an obsession to discover. We can cultivate in our students the disposition to be curious and, through this, the skills of inquiry.

Share some examples of curious artists and scientists (you might draw on student responses from Pre-visit Activity 2: Looking Two Ways), taking note of the variety of investigation and expression methods. Introduce the idea of a *Wunderkammer*, or a curiosity cabinet. Curiosity cabinets historically included a plethora of attractive and interesting objects, products of both nature and humans. For more information about *Wunderkammern*, see the Art Institute of Chicago’s teacher manual, *Faces, Places & Inner Spaces*: www.artic.edu/aic/collections/citi/resources/Rsrc_001277.pdf

Next, ask students to practice being curious—to identify something they want to know more about.

- As you experience the world around you, what are you curious about?
- What questions emerge from your curiosity?
- How do you think you might answer your questions?

After identifying their investigation, ask students to collect a variety of natural objects, human-made objects, and scientific instruments that relate to their inquiry. Students can create their own “curiosity cabinet” to organize and showcase their investigation. They could use a shoebox or other container, or document their investigation through photographs and create a digital curiosity cabinet.

Ask students to consider how they have organized and displayed their objects as a reflection of their investigative process or the nature/topic of their curiosity.

Present the cabinets in the classroom and allow students a few minutes to look at one another’s creations. Ask them to look closely at the objects that have been collected and to reflect on the objects’ characteristics. What curiosities were investigated in the class? Which object types were most commonly collected? What methods were used to tell stories (through organization and display) about the curiosities? What does your collection, and how you presented your objects, say about you as an artist or scientist, or both?

Post-visit Activity 4: Sharing Feedback

Have students track their observations on a subject of their choice over the course of a week. Discuss different modes for recording their observations, including writing, audio recording, or drawing, and encourage students to use a mixture of these modes. At the week’s end, ask students to form and document at least two hypotheses to explain what they observed and what additional information they need to test their hypotheses. Have students review one another’s work and provide feedback in the form of questions (such as questions that begin with “I wonder...”).

Ask students to reflect on the process of observation, sharing their findings, and receiving feedback. Through short essays, respond to the following questions:

- What did you do when you ran into problems, experienced unexpected outcomes, or had new questions?
- How did you respond to your intuition?
- How did you engage your imagination?
- Was it valuable to share what you discovered along the way and solicit feedback?
- How did you respond to your classmate’s feedback?
- If you think you have answered your questions and those provided by classmates’ feedback, what do you do next?

Post-visit Activity 5: Stability and Change—An Art Historical Perspective

Examining a single work of art provides many opportunities to consider the scientific concepts of stability and change. Through observation and analysis of the physical materials, we might understand how the object has been altered by and survived the effects of environmental or human interventions. We might also reflect on an artist’s compositional choices that create the perception of stability and/or change, engaging our attention and helping us make meaning from what we see.

While all of this is possible with one single work of art, we can further explore stability and change as critical components of the creative process when we look at and compare multiple examples from an artist’s body of work. While we often think of an artist as having a “signature style,” over time his or her technique, subject matter, and materials will likely evolve and change—in small or large ways

and due to a variety of factors. By looking closely at a series of artworks and examining biographical information, we can better understand the constants and the variables in an artist's career.

Activity: Listed below are four works of art by two different artists (reproductions for classroom use are included at the end of this resource). Using the prompts, have students investigate all four of the artworks of one or both artists.

Georgia O'Keeffe (1887–1986)

Blue and Green Music, 1919/21

Shelton with Sunspots, 1926

Red and Pink Rocks and Teeth, 1938

Sky Above Clouds, 1965

Georgia O'Keeffe grew up on a farm near Sun Prairie, Wisconsin. Her family encouraged her artistic skills, and she began art lessons at a young age. She received a traditional training that focused on painting in a realistic style. At age 28, however, she took her art in a different direction. She started using only simple lines to represent things and drew abstract shapes to express her feelings and thoughts. Her art impressed Alfred Stieglitz, a photographer and art dealer in New York City, who encouraged her to move there. Stieglitz belonged to a group of artists who, like O'Keeffe, had turned away from traditional styles to create art that reflected modern times—an idea later called Modernism. O'Keeffe joined the group in New York. At that time, O'Keeffe found particular inspiration in the city's tall buildings. She was also excited by the new ways of looking at the world provided by the camera. Seen through the camera's lens, sunlight on the city's structures became shimmering spots and tiny details were magnified. O'Keeffe used these new perspectives in her paintings. In 1929, O'Keeffe made her first trip to New Mexico, and it became her permanent home in 1949. O'Keeffe loved the desert and studied its landscapes for years. She painted desert scenes that were both realistic and abstract. In some pictures, precisely painted animal bones and flowers seem to float in space. In others, she showed details of the desert very close up or from far away. She chose to simplify details and focused on colors and shapes. In her 70s, O'Keeffe began to travel widely, including her first trips in an airplane. The views she saw high in the air sparked a new series of paintings. She continued to paint and draw into her 90s. She died at age 99 in Santa Fe, New Mexico.

Diego Rivera (1886–1957)

Portrait of Marevna, c.1915

Still Life with an Apple, 1918

The Weaver, 1936

Portrait of Florence Arquin, 1943

Diego Rivera was born in Guanajuato, Mexico. A talented art student, Rivera earned a scholarship in 1907 to visit Europe. He lived there for most of the next decade. In Spain, France, and Italy, Rivera studied masterworks of the past and explored new artistic styles. He experimented with Cubism, a style that breaks images into sharp angles and shows different views of an object at the same time. In his Cubist works, Rivera painted people by layering triangles, rectangles, and other geometric shapes. He also added patches of bright patterns and different textures to set the scene. Rivera switched to a more realistic style around 1917, but he continued to think about geometric shapes. He made pencil sketches of everyday items arranged in groups. He focused on showing the objects' basic forms and how they overlapped—similar to the layered shapes in his Cubist paintings. When Rivera returned to Mexico in 1921, just after the end of the Mexican Revolution, he and other artists wanted to create art to portray the people and traditions of their homeland. Rivera's art of this time combined simple, rounded shapes with strong colors, and used layers of brushstrokes to show different textures. His painted scenes included details of the daily lives of native people, but often gave them a larger-than-life feeling. In the mid-1920s, he began painting large murals on public buildings that brought him international fame by the 1930s. The murals in Mexico and the United States reflected his belief that art should be available to everyone—not just the wealthy—and his scenes celebrated farmers, craftspeople, and factory workers. He included images of political leaders in several of the murals, which at times upset those who disagreed with Rivera's politics. In addition to these large murals, Rivera continued to make smaller works. He painted numerous portraits of his friends and fellow artists. Rivera died at age 70 in Mexico City, leaving a legacy of political activism and public art.

Prompts for Investigating a Set of Artworks:

1. Select one of the artists and look closely at their works of art. Using your field investigation guide, make written or drawn notes about what you notice in the artist's work. Just by looking, consider their style and technique; use of color, line, and shape/form; and materials. Note what seems to be the same across all four images and what seems to change. Use the dates of the works to chart the progress of any changes you notice.
2. Read the brief essay about each artist. Consider what details in the essay might help to explain the elements that stayed the same and those that changed.
3. What else do you want to know about the artist and his or her art or life?
4. Can you summarize what you learned about this artist and his or her work?
5. What new ideas or questions do you have about the creative process after looking at this artist's work?

Standards Alignment

National Curriculum Standards and Learning Initiatives

The following list identifies the primary and secondary standards addressed in this curriculum resource.

1. Common Core State Standards: Reading

CCSS.R.1 Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text

CCSS.R.2 Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas.

CCSS.R.5 Analyze the structure of texts, including how specific sentences, paragraphs, and larger portions of the text (e.g., a section, chapter, scene, or stanza) relate to each other and the whole.

CCSS.R.6 Assess how point of view or purpose shapes the content and style of a text.

CCSS.R.7 Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.

CCSS.R.10 Read and comprehend complex literary and informational texts independently and proficiently.

**The Common Core reading standards can be successfully applied to observation and analysis of visual images, strengthening visual literacy skills that are transferrable to text-based literacy.*

2. Common Core State Standards: Speaking and Listening

CCSS.SL.1 Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

CCSS.SL.2 Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

CCSS.SL.4 Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

3. Common Core State Standards: Reading Standards for Literacy in Science and Technical Subjects

CCSS.RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

CCSS.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades*

6-8 texts and topics.

CCSS.RST.6-8.5 Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.

CCSS.RST.6-8.6 Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

CCSS.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

CCSS.RST.6-8.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

**The Common Core reading standards can be successfully applied to observation and analysis of visual images, strengthening visual literacy skills that are transferrable to text-based literacy.*

4. National Core Arts Standards

Connect: Relating artistic ideas and work with personal meaning and contextual knowledge.

Create: Conceiving and developing new artistic ideas and work.

Present (visual arts): Interpreting and sharing work.

Respond: Interacting with and reflecting on artistic work and performances to develop understanding.

5. Next Generation Science Standards: Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural systems.

Stability and Change: Small changes in one part of a system might cause large changes in another part.

Structure and Function: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

Systems and System Models: Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.

Bibliography

Selected Print Resources

Callen, Anthea. *The Spectacular Body: Science, Method, and Meaning in the Work of Degas*. New Haven: Yale University Press, 1995.

The Spectacular Body explores the ways in which the human body—especially the female body—was visualized by artists in late nineteenth-century Paris. Focusing on the work of Degas, it deals with issues of sexuality, gender, and visual representation to illuminate the underlying meanings of the famed Impressionist's depictions of women in his series of bathers, dancers, and prostitutes.

The Art Institute of Chicago. *Impressionism and Post-Impressionism*, teacher manual. The Art Institute of Chicago, 1995. An extensive range of suggested classroom applications furnishes ready tools to help the teacher integrate the Art Institute of Chicago's distinguished collection of Impressionist art into a variety of disciplines, both within the school and at the museum. <http://www.artic.edu/aic/resources/resource/1522>

The Art Institute of Chicago. *Many Faces: Modern Portraits and Identities*, teacher manual. The Art Institute of Chicago, 1997. This teacher manual on modern portraits and identities is intended to emphasize that human identity is as much something constructed as the result of genetics. The ten works of art included in this manual were chosen to convey a broad definition of modern portraiture, in which one or more portrait elements might predominate in a given work. <http://www.artic.edu/aic/resources/resource/1411>

Bronowski, J. *The Ascent of Man*. Boston and Toronto: Little, Brown and Company, 1973. This volume traces the development of human society through our understanding of science.

Carroll, Colleen. *The Elements: Earth, Air, Fire, Water*. New York: Abbeville Kids, c1996. Examines how the four elements have been depicted in works of art from different time periods and places.

Clair, Jeanes, Editor. *Cosmos: from Romanticism to the Avant-Garde*. Montreal, Quebec: Montreal Museum of Fine Arts; Munich; New York: Prestel, 1999. Catalog of an exhibition held at the Montreal Museum of Fine Arts, June 17-Oct 17, 1999 and the Centre de Cultura Contemporània de Barcelona, Nov. 23, 1999-Feb. 20, 2000.

Greenberg, Barbara R. *Art in Chemistry, Chemistry in Art*. Westport, Conn.: Teacher Ideas Press, 2008. Integrate chemistry and art with hands-on activities and fascinating demonstrations that enable students to see and understand

how the science of chemistry is involved in the creation of art.

Ede, Sian. *Art and Science*. London; New York: I. B. Tauris, 2005.

While demonstrating how science is affecting the creation and interpretation of contemporary art, this book proposes that artistic insights are as important on their own terms as those in science and that we can and should accommodate both forms of knowledge.

Hawthorne, John G. and Cyril Stanley Smith. *Theophilus on Divers Arts: The Foremost Medieval Treatise on Painting, Glassmaking and Metalwork*. New York: Dover Publications, 1979. Earliest (12th century) treatise on arts written by practicing artist. Pigments, glass blowing, stained glass, gold and silver work, more.

Kalbag, Asha. *Computer Graphics & Animation: An Osborne Computer Guide*. Tulsa, Oklahoma: EDC Publishing, 1999. This guide is designed for complete beginners and those who want to build on their experience. It is full of practical tips and useful information, exploring the use of computer graphics for both entertainment and work.

Kemp, Martin. *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat*. New Haven: Yale University Press, 1990.

In this illustrated book, Martin Kemp examines the major optically oriented examples of artistic theory and practice from Brunelleschi's invention of perspective and its exploitation by Leonardo and Durer to the beginnings of photography.

Kohl, Maryann. *Science Arts: Discovering Science through Art Experiences*. Bellingham, WA: Bright Ring Pub., 1993. Children explore the world of science through art with these open-ended experiments categorized by scientific topic. Hundreds of art activities amaze and delight children as they discover the magic of crystals, light, constellations, plants, and more. A unique approach to learning basic science concepts.

Los Angeles County Museum of Art. *The Visible World [kit]: Observation in Art and Science*. 1999. The six slides in this packet span a variety of cultures and historical periods. Representing a diverse selection of media and subject matter, these slides can serve as a wonderful introduction to some of the ways artists represent the natural world and as a catalyst for thinking about the worlds of art and science.

Miller, Arthur I. *Colliding Worlds: How Cutting-Edge Science Is Redefining Contemporary Art*. New York: W. W. Norton & Company, 2014. In "Colliding Worlds," the historian and philosopher Arthur I. Miller argues that artists and scientists have always had the same mission: to "fathom the reality beyond appearances, the world in-

visible to our eyes." And he argues that after drifting apart during the Enlightenment, the twin branches of understanding have been coming back together over the last century, a reunification that is accelerating in the digital age.

Miller, Jonathan. *On Reflection*. London: National Gallery, 1998. Published to accompany an exhibition entitled Mirror image: Jonathan Miller on reflection, at the National Gallery, London, 16 September-13 December 1998.

National Science Education Standards: Observe, Interact, Change, Learn. Washington, DC: National Academy Press, c1996. Americans agree that our students urgently need better science education. But what should they be expected to know and be able to do? Can the same expectations be applied across our diverse society? These and other fundamental questions are addressed in Nation Science Education Standards.

Nemett, Barry. *Images, Objects and Ideas: Viewing the Visual Arts*. New York: Holt, Reinhart, and Winston, Inc., c. 1992. This topically-organized text gives a clear introduction to the elements, principles, and media of art, and helps your students learn to make their own interpretations.

Paris, Scott G., Editor. *Perspectives on Object-centered Learning in Museums*. Mahwah, N.J.: Lawrence Erlbaum Associates, c2002.

Originating in a NSF conference held at the University of Michigan, this book examines the latest ideas about how children interact with objects and through that interaction acquire new understandings, attitudes, and feelings.

Rhodes, Lynette I. *Science within Art*. Cleveland, Ohio: Cleveland Museum of Art; Bloomington, Ind.: distributed by Indiana University Press, c1980. Catalog of an exhibition at the Cleveland Museum of Art.

Smith, Cyril Stanley. *A Search for Structure: Selected Essays on Science, Art and History*. Cambridge: MIT Press, 1981. Science, art, and history all share common or analogous patterns of hierarchical order that are embedded into the structure of the material world as well. This is a central insight of these essays by a generalist who has also spent a lifetime working in his specialty, the nature of materials.

Stafford, Barbara Maria. *Artful Science: Enlightenment, Entertainment and the Eclipse of Visual Education*. Cambridge: MIT Press, 1994. *Artful Science* reveals the exhilarating but paradoxical intertwining of enchantment with enlightenment in the early modern period. A cross-disciplinary guide to intellectual high and low life of the eighteenth century, *Artful Science* makes the case for the pedagogical opportunities inherent in an oral-visual culture

Stafford, Barbara Maria and Frances Terpak. *Devices of Wonder*. Los Angeles: Getty Research Institute, 2001.

This book explores the artful machines humans have used to augment visual perception. The encyclopedic cabinet of curiosities serves as a model for this study of the archaic instruments lurking in state-of-the-art technology. Barbara Stafford's introduction weaves these fascinating artifacts into a provocative narrative analyzing the complex links between old and new media.

Strosberg, Eliane. *Art and Science*. New York: Abbeville Press, 2001. A wide-ranging discussion on the intersections of art and science, this clearly illustrated volume provides an accessible introduction to an enduring dialogue.

Taylor, Joshua. *Learning to Look, a Handbook for the Visual Arts*. Chicago: The University of Chicago Press, 1981. This handy guide to the visual arts is designed to provide a comprehensive view of art, moving from the analytic study of specific works to a consideration of broad principles and technical matters.

Thompson, Daniel V. *The Materials and Techniques of Medieval Painting*. New York: Dover Publications, 1956. In this volume, an internationally known authority on medieval paint technology describes these often jealously guarded recipes, lists of materials, and processes. Based upon years of study of medieval manuscripts and enlarged by laboratory analysis of medieval paintings, this book discusses carriers and grounds, binding media, pigments, coloring materials, and metals used in painting.

Tolley, Kimberley. *The Art and Science Connection: Hands-on Activities for Intermediate Students*. Menlo Park, Calif.: Addison-Wesley, c1994. To help primary students make a connection between art and science, a collection of hands-on activities have been developed. By engaging in these activities that integrate art and science, students learn a variety of ways through which they can understand the world. They learn to bring creativity and insight to the discipline of science, and method and order to the discipline of art.

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Wilson, Stephen. *Art + Science Now*. London: Thames & Hudson, 2010. A global overview of the ways in which contemporary artists

draw on kinetics, biology, robotics and information technologies to explore new forms of creative expression.

Young, Jay. *The Art of Science: A Pop-up Adventure in Art*. Cambridge, Mass.: Candlewick Press, 1999.

The Art of Science explores the many and often surprising ways in which science has influenced and inspired artists through the ages. And with interactive pop-ups throughout, you can join the exploration on every page to reveal the relationship between science and art.

Zeki, Semir. *Inner Vision: An Exploration of Art and the Brain*. Oxford: Oxford University Press, 1999.

In *Inner Vision*, one of the founders of visual neuroscience, Semir Zeki, offers the first attempt to apply the science of vision to painting and sculpture, revealing how the conception, execution, and appreciation of the visual arts are all shaped by the anatomy of the brain

Conservation

Bomford, David. *Conservation of Paintings*. London: National Gallery, 2009.

This volume discusses the material nature of paintings and the ways that they have changed, both naturally and at the hands of previous restorers. It also describes the main types of conservation treatment carried out on panel and canvas paintings and some of the complex issues involved in cleaning and restoration.

Holden, Carol D. *Historic Preservation Education [kit]*. 1980
A guide for educators to help their students improve their perception of the environment. This guide embodies many disciplines such as social studies, reaching, vocabulary, mathematics and language arts as well as aesthetics.

Los Angeles County Museum of Art. *Preserving the Past [kit]: Conservation at the LACMA*. 1995.

This teacher's resource packet provides an introduction to the field of conservation, some of the common threats to art objects, and measures for preventative care. Furthermore it is hoped that this packet will help teachers to impact to their students why the protection of cultural property is an important endeavor.

Light and Color

Bluhm, Andreas. *Light!: The Industrial Age 1750-1900: Art & Science, Technology & Society*. New York: Thames & Hudson, 2001.

Published in conjunction with the exhibition of the same name (Van Gogh Museum, Amsterdam, October 2000-February 2001, and Carnegie Museum of Art, Pittsburgh, April 2000-July 2001).

Delamare, Francois. *Colors: The Story of Dyes and Pigments*. New York: H.N. Abrams, 2000.

From the painted caves at Lascaux, 40,000 years old, to the medieval cloth industry to today's computerized chemistry, this book surveys the history of dyes and pigments.

Lynch, David K. *Color and Light in Nature*. Cambridge, UK;

New York: Cambridge University Press, 2001.

This guide provides clear explanations to all naturally occurring optical phenomena seen with the naked eye, including shadows, halos, water optics, mirages and a host of other spectacles. Separating myth from reality, it outlines the basic principles involved, and supports them with many figures and references.

Rossing, Thomas. *Light Science: Physics and the Visual Arts*. New York: Springer, c1999.

This book is intended for students in the visual arts and for others with an interest in art, but with no prior knowledge of physics. It presents the science of light—that is, the science behind what and how we see. The approach emphasizes phenomena rather than mathematical theories and the joy of discovery rather than the drudgery of derivations - the opposite of “heavy science.”

Rossing, Thomas D., Editor. *Teaching Light & Color*. American Association of Physics Teachers, 2001.

This collection of scientific papers, articles, and brief excerpts from books is intended to provide teachers with source material for teaching light and color. It also contains references to some 281 books, papers and websites.

Rossotti, Hazel. *Colour*. Princeton, N.J.: Princeton University Press, 1984, c1983.

Hazel Rossotti uses scientific basics—matter, energy, and eye structure—to discuss the colors of the natural world, the mechanism of color vision, and a range of color technology from ceramics to television.

Selected Web Resources

Art, Science, and Technology website by the Art institute and Chicago

With primary emphasis on the theme of light and color, this resource, conceptually integrated with Illinois State Goals and Chicago Academic Standards, reveals how the scientific method is applied to the making, conserving, and exhibiting of art. This website is designed for all teachers, who are invited to make use of its contents as points of departure for their own explorations with their students of science, art, or technology.

<http://www.artic.edu/aic/education/sciarttech/>

Audio Lecture: Science Chicago—A Technical Study of *A Sunday on La Grande Jatte*

Inge Fiedler, Conservation Microscopist, discusses the technical study of Georges Seurat's *A Sunday on La Grande Jatte 1884*, painted between 1884 and 1886. Learn how it was created from someone who has examined the painting very, very closely.
http://www.artic.edu/aic/resources/resource/862?search_no=11&index=2

Lesson Plan: Plant and Animal Classification

In this lesson plan, students will use a painting by Frans Syders to learn more about the development of the scientific system for classifying plants and animals.

http://www.artic.edu/aic/resources/resource/1028?search_no=10&index=9

Lesson Plan: Art and Geology

In this lesson, students will research volcanoes after examining and discussing *View of Cotopaxi*. They will return to the painting to explore how Frederic Edwin Church enhanced his view, and then create their own drawing of Cotopaxi erupting that reflects the current information they have gathered about Cotopaxi and volcanoes in general.

http://www.artic.edu/aic/resources/resource/1241?search_no=8&index=10

Art and Science: A Curriculum for K-12 Teachers

The Getty Museum's free, downloadable lesson plans for teachers in grades K–12. Includes an image bank, bibliography, and education standards charts.

http://www.getty.edu/education/teachers/classroom_resources/curricula/art_science2/

Art and Science Collaborations

Compendium of international art and science research collaborations.

<http://www.asci.org>

Artful Thinking

Research and resources from Project Zero at the Harvard Graduate School of Education.

<http://www.pzartfulthinking.org/index.php>

Arts across the Curriculum, Grades K-5

National Education Association lesson plans and related resources.
<http://www.nea.org/tools/lessons/Arts-Across-the-Curriculum-K-5.html>

Arts across the Curriculum, Grades 6-8

National Education Association lesson plans and related resources.
<http://www.nea.org/tools/lessons/Arts-Across-the-Curriculum-Grades-6-8.html>

Connecting Art and Science

Science Friday exploration of how art and science are connected, with commentary from Cormac McCarthy, Werner Herzog, and Lawrence Krauss.

<http://www.sciencefriday.com/segment/04/08/2011/connecting-science-and-art.html>

Edutopia Arts Integration

Lesson plans and templates for teachers in grades 6-8.
<http://www.edutopia.org/stw-arts-integration-resources-lesson-plans-graph1>

Growing from STEM to STEAM

Kennedy Center's Arts Edge resources on STEAM learning and teaching.
<https://artsedge.kennedy-center.org/educators/how-to/growing-from-stem-to-steam>

Integrating the Arts

Lesson plans for K-12 teachers from the Walters Art Museum.
<http://thewalters.org/teachers/resources/lesson-plans/>

North Carolina Museum of Art, “Elements, Compounds, and Pigments”

Lesson plan: Students will understand how the discovery of new elements (such as cobalt, cadmium, and chromium) in the 1700s and early 1800s led to the creation of new artistic materials, which led to the innovations in artistic style made by impressionist painters in the late 1800s.

<http://artnc.org/lessons/elements-compounds-and-pigments>

Scholastic Arts Integration

Project ideas and related resources for art-science integration.
<http://www.scholastic.com/teachers/top-teaching/2012/10/art-integration-easy-ideas-combining-science-and-art>

Science and Art Conservation for Teachers

Lesson plans and supporting materials from Emory University on art conservation, covering adhesives, corrosion, fibers, pigments, paper, wood, and more.

<http://carlos.emory.edu/science-art-conservation>

STEM to STEAM

Research and resources from the Rhodes Island School of Design.
<http://stemtosteam.org>

Symbiartic

Art and science blog from *Scientific American*.
<http://blogs.scientificamerican.com/symbiartic/>

The Enduring Relationship of Science and Art

Lecture and content on connecting the disciplines from the Art Institute of Chicago.

<http://www.artic.edu/aic/education/sciarttech/2a1.html>

The Synergy Project

Video case studies of art and science collaborations; a NSF project, initiated by MIT and Woods Holes Oceanographic Institution.
<http://science360.gov/series/synergy-project-experiment-art-science-collaboration/13c20997-be8f-48a8-8d18-5bbfe37378ef>

Teach arts and sciences together

TED Talk by Mae Jemison.
http://www.ted.com/talks/mae_jemison_on_teaching_arts_and_sciences_together?language=en

Conservation

Conservation and Scientific Research Projects

Multimedia introduction to a dozen key conservation projects at the Metropolitan Museum of Art.

<http://www.metmuseum.org/research/conservation-and-scientific-research>

Art + Science

Conservation at LACMA

A peek into specific conservation projects and practices at the Los Angeles County Museum of Art.

<http://www.lacma.org/art/exhibition/conservation>

Conservation at the National Gallery of Art

Introduction to the conservation research projects at the National Gallery of Art, including works on paper, paintings, textiles, photographs, and more.

<http://www.nga.gov/content/ngaweb/conservation.html>

Conservation Science

Introduction to the laboratory, instrumentation, and research projects at the Indianapolis Museum of Art.

<http://www.imamuseum.org/research/conservation-science>

Getty Conservation Institute

Introduction to the work at the J. Paul Getty Trust's Getty Conservation Institute.

<http://www.getty.edu/conservation/about/science/>

Protecting and Preserving the Collection

Project case studies, videos, and related resources for conservation at the Museum of Modern Art.

<http://www.moma.org/explore/collection/conservation/-projects>

Smithsonian Museum Conservation Institute

In-depth look at current and previous research conservation projects at the Smithsonian.

<http://www.si.edu/mci/english/research/index.html>

Images

Charles Ray (American, born 1953)

Hinoki, 2007

Cypress wood

5'7" (height) x 25" (length) x 19'7" (depth)

Through prior gifts of Mary and Leigh Block, Mr. and Mrs. Joel Starrels, Mrs. Gilbert W. Chapman, and Mr. and Mrs. Roy J. Friedman; restricted gift of Donna and Howard Stone. 2007.771

Pablo Picasso (Spanish, worked in France, 1888-1973)

The Red Armchair, December 16, 1931

Oil and ripolin on panel

51 5/8 x 38 7/8 in. (131.1 x 98.7 cm)

Gift of Mr. and Mrs. Daniel Saidenberg. 1957.72

© 2013 Estate of Pablo Picasso / Artists Rights Society (ARS), New York.

William Victor Higgins (American, 1884-1949)

Spring Rains, c. 1924

Oil on canvas

102.2 x 109.9 cm (40 1/4 x 43 1/4 in.)

Friends of American Art Collection. 1924.18

Berthe Morisot (French, 1841-1895)

Woman in a Garden, 1882/83

Oil on canvas

48 1/2 x 37 in. (123 x 94 cm)

A Millennium gift of Sara Lee Corporation. 1999.363

Robert Delaunay (French, 1885-1941)

Champs de Mars: The Red Tower, 1911/23

Oil on canvas

63 1/4 x 50 5/8 in. (160.7 x 128.6 cm)

Joseph Winterbotham Collection. 1959.1

Thembu

WEDDING ENSEMBLE FOR A GROOM (UMYENI), 1950s

Cotton cloth, glass beads, mother of pearl beads, thread, leather, wool, and metal

Skirt height: 65.5cm (25 3/4 in.)

Restricted gift of the Woman's Board of The Art Institute of Chicago; partial gift of Axis Gallery (Gary Van Wyk and Lisa Brittan). 1998.519

Burma (Myanmar)

Crowned and Bejewelled Buddha Seated on an Elephant Throne, late 19th century

Gilded and lacquered wood with paint and colored glass

144.5 x 85.2 x 49.2 cm (56 7/8 x 33 9/16 x 19 3/8 in.)

James W. and Marilyn Alsdorf collection. 1983.979

Upper Missouri River Tribe (Missouri, United States)

War Shirt, 1830/40

Deer hide, ermine tails, glass pony beads, hair, porcupine quills, and trade cloth

Approximately 101.6 x 50.8 cm (40 x 20 in.)

Frederick W. Renshaw, Ada Turbull Hertle, and Curator's Discretionary fund. David Soltker and Irving Dobkin endowments; Restricted gifts of Mrs. Leonard S. Florsheim, Jr., The Donnelley Foundation and Cynthia and Terry Perucca. 2004.485

Jean Baptiste Joseph Wicar (French, 1762-1834)

Virgil Reading the "Aeneid" to Augustus, Octavia, and Livia, 1790/93

Oil on canvas

43 3/4 x 56 1/8 in. (111.1 x 142.6 cm)

Wirt D. Walker Fund. 1963.258

Joseph Cornell (American, 1903-1972)

Untitled (Hotel de la Duchesse-Anne), 1957

Box construction

17 5/8 x 12 1/4 x 4 7/16 in.

Lindy and Edwin Bergman, Joseph Cornell Collection. 1982.1868

Georgia O'Keeffe (American, 1887-1986)

Blue and Green Music, 1919/21

Oil on canvas

58.4 x 48.3 cm (23 x 18 in.)

Alfred Stieglitz Collection, gift of Georgia O'Keeffe. 1969.835

Georgia O'Keeffe (American, 1887-1986)

The Shelton with Sunspots, N.Y., 1926

Oil on canvas

123.2 x 76.8 (48 1/2 x 30 1/4 in.)

Gift of Leigh B. Block. 1985.206

Georgia O'Keeffe (American, 1887-1986)

Red and Pink Rocks and Teeth, 1938

Oil on canvas

53.3 x 33 cm (21 x 13 in.)

Alfred Stieglitz Collection, gift of Georgia O'Keeffe. 1955.1223

Georgia O'Keeffe (American, 1887-1986)

Sky Above Clouds IV, 1965

Oil on canvas

243.8 x 731.5 cm (96 x 288 in.)

Restricted gift of the Paul and Gabriella Rosenbaum Foundation; gift of Georgia O'Keeffe. 1983.821

Diego Rivera (Mexican, 1886-1957)

Portrait of Marevna, c.1915

Oil on canvas

145.7 x 112.7 cm (57 3/8 x 44 3/8 in.)

Alfred Stieglitz Collection, gift of Georgia O'Keeffe. 1957.628

Diego Rivera (Mexican, 1886-1957)

Still Life with an Apple, 1918

Graphite on tan laid paper

238 x 314 mm

Bequest of Walter S. Brewster. 1954.1078

Diego Rivera (Mexican, 1886-1957)

The Weaver, 1936

Tempura and Oil on canvas

66 x 106.7 cm (26 x 42 in.)

Gift of Josephine Wallace KixMiller in memory of her mother, Julie F. Miller, who purchased the painting from the artist at his studio in Mexico in 1936. 1998.529

Diego Rivera (Mexican, 1886-1957)

Portrait of Florence Arquin, 1943

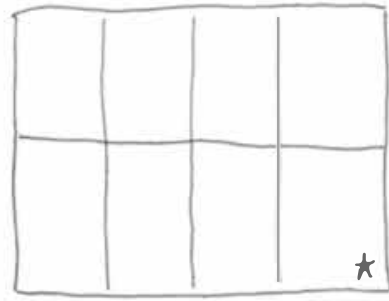
Oil on canvas

54.9 x 43.2 cm (21 5/8 x 17 in.)

Gift of Mr. and Mrs. Samuel A. Williams. 1972.1223

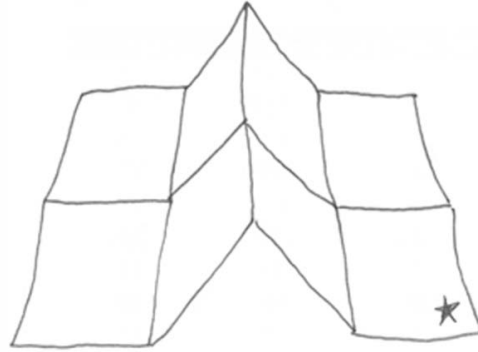
A short guide to folding an eight-page mini-zine

1 Fold a standard piece of white copy paper (8.5 x 11 inches) into eight even parts like so:

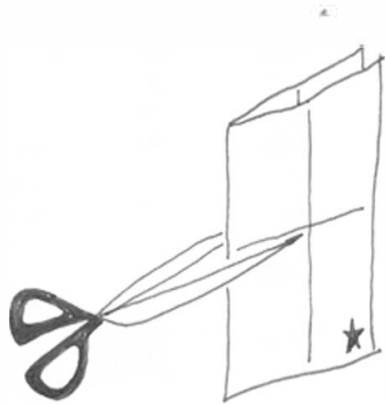


(the little star helps tell you where you are!)

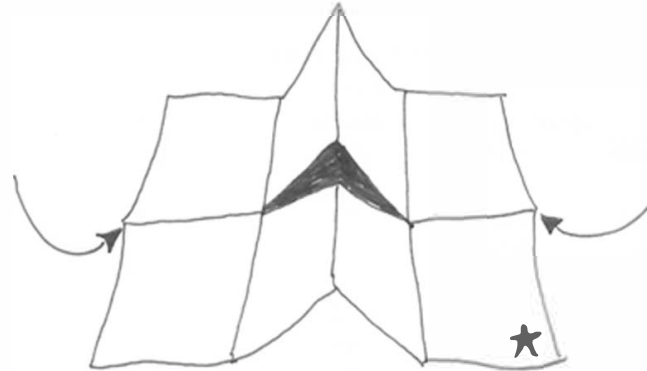
2 Now crease those folds so the paper rests like this naturally:



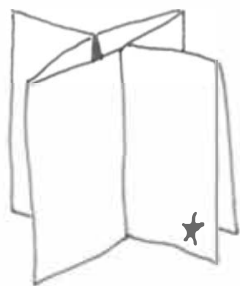
3 Now fold the paper in half as below and cut it halfway through so it looks like "4":



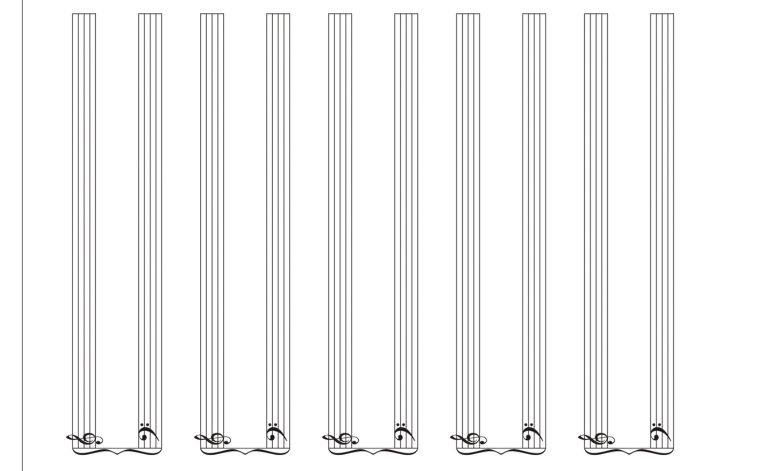
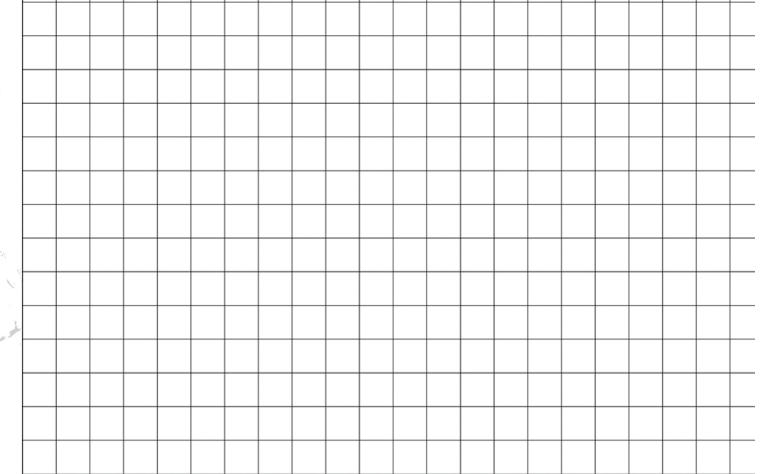
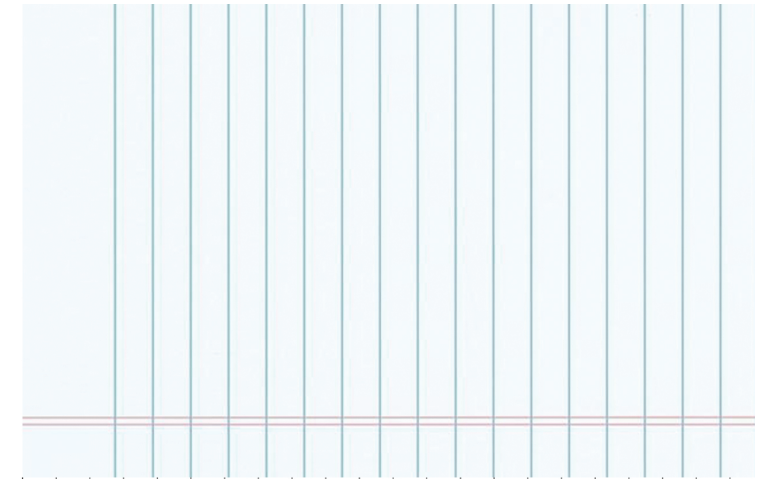
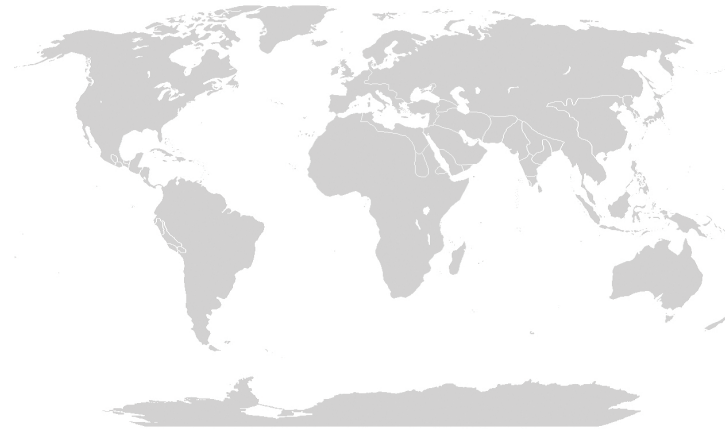
4 Place the paper down like so. Now put your index fingers where the arrows are, lifting up while folding the sheet lengthwise over your index fingers:



5 Continuing step 4, the middle of the sheet should buckle so that it can fold into this form naturally:



6 And now you have your eight-page zine! Notice the "starred" page is the front page of the zine. Voila!



**BE AN ARTIST
BE A SCIENTIST
BE CURIOUS**

**I HAVE NO SPECIAL
TALENTS. I AM ONLY
PASSIONATELY
CURIOUS.
-ALBERT EINSTEIN**