STE(A)M Tour: Grades K-12

"Both fields are engaged in research. Both fields put forth hypotheses and test them to see if they are true. The tools for research may be different, but both fields are exploring ideas rigorously. Both fields build and expand their knowledge based on previous work done. Both fields are looking for answers. At points of intersection, I think that art can expand science and vice versa to help push both fields forward." – Arthur Huang

Alexander Calder, *Five Rudders*, 1964. Painted sheet metal and rods, 126 x 98 ¼ x 112". Mildred Lane Kemper Art Museum, Washington University in St. Louis. Gift of Mrs. Mark C. Steinberg, 1964. Copyright: Artists Rights Society (ARS).

Objectives: This guide is designed as a multidisciplinary companion for K-12 educators bringing their students to the Mildred Lane Kemper Art Museum. Our intent is to offer a range of learning objectives, gallery discussions, and postvisit suggestions to stimulate the learning process; encourage dialogue; emphasize the interconnectedness of art, science, technology, engineering, and math; and help make meaning of the art presented. Teachers at all grade levels should glean from this guide what is most relevant and useful to their students.

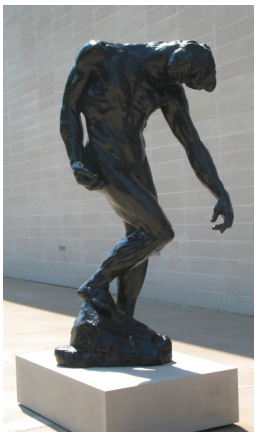
Before You Visit: Discuss the relationship of art to science, technology, engineering, and math. Review concepts to be discussed during the tour. See the resources at the end of this guide for more information. Please note that **bolded** words are possible vocabulary words.

Alexander Calder, *Five Rudders* (1964)

The circus, animals, and the solar system often inspired Alexander Calder's artwork, but this sculpture draws heavily on ship imagery, as evidenced in the prominent bolts, use of sheet metal, rudder-like shapes, and, of course, the title. Calder's knowledge of engineering, which he studied in college, gave him the tools to experiment with kinetic sculpture, ultimately leading to the creation of his signature **mobiles** (which hang from the ceiling) and **stabiles** (which balance on a base). Mobiles and stabiles both rely on various scientific and mathematical concepts such as **balance**, the **Law of Levers**, and algebra. The Law of Levers, developed by the Greek mathematician Archimedes in 260 BCE, states that the weight of objects placed or suspended on one side of a lever multiplied by their distance from the **fulcrum** must equal that of the other side.[1] In other words: $W_R \times D_R = W_L \times D_L$. A balanced equation ensures that the sculpture will remain in **equilibrium**.

Discussion Questions: What does this sculpture look like to you? Can you find any references to animals or space? Let's explore balance: stand on one foot with your arms tight to your chest, then hold your arms out—which way is easier to balance? Does it seem like any part of this sculpture might be imbalanced? Where and how do you see the Law of Levers working in this sculpture? Other mathematical concepts and analytical skills involved in sculptures by Alexander Calder could include proportional reasoning, inverse relationships, pattern recognition, and generalization.

[1] http://www.jstor.org/stable/pdfplus/30216026.pdf?acceptTC=true



Auguste Rodin, *The Shade*, 1880. Bronze, 74 ¼ x 35 ½ x 31". Mildred Lane Kemper Art Museum, Washington University in St. Louis. Gift of Morton D. May in honor of William N. Eisendrath, Jr., 1968.

Auguste Rodin, *The Shade* (1880)

Auguste Rodin's figure of the shade is based on the shades (souls of the damned) in Dante's *Divine Comedy*, who stand outside the entrance to Hell pointing to the unequivocal inscription, "Abandon hope, all ye who enter here." A version of Rodin's *Three Shades* famously stand atop his monumental sculpture *The Gates of Hell* (1880–c. 1890), but the shades also appear alone, as studies, and as enlarged, independent statues.[2] Mulitiple copies of this statue exist, thanks to the three-dimensional reproduction practice of casting. Rodin and his studio assistants produced a large number of plaster casts, but Rodin also worked in clay, marble, and bronze, producing casts in the **lost-wax bronze casting** and **sand casting** techniques. The lost-wax technique can take two forms: direct or indirect. The direct method uses and therefore destroys the original wax model, while the indirect method creates bronze casts from a reusable plaster cast taken from the original wax model.[3] However, most of Rodin's work is actually sand cast, the main method of production in mid-19th-century France.[4] In sand casting, the model is pressed into special sand to leave a negative imprint from which a positive cast is then made. The casts are usually hollow. Essential to the bronze casting process is, of course, the creation of bronze itself. Bronze is an **alloy**—a mixture of two or more metals—of **copper** and **tin**, occasionally with very small amounts of **zinc**. The metals are mixed together in a **liquid** form and cooled to room temperature to form a **solid**.

Discussion Questions: What are the qualities of wax that make it a good sculpting material? Why might an artist choose to work with marble, clay, or bronze? How does each material look and feel? Discuss the chemistry involved in bronze casting: what is required to change bronze from a solid to a liquid and vice versa? Look around (but do not touch) other sculptures on the plaza—how do they appear similar to and different from Rodin's sculpture?

Dan Peterman, *Accessories to an Event* (2006)

This sculpture is made of post-consumer recycled plastic. Plastics are **polymers**, chains of repeating **monomers** (small molecules) chemically bound together, typically through a **condensation reaction**.[5] Plastic is usually made of **petroleum** , a carbon-based substance derived from crude oil, which, like natural gas and coal, is a **fossil fuel**.[6] Carbon-rich organic matter, like plant life, is transformed into fossil fuels through exposure to heat and pressure in the earth's crust over millions of years. The geologic amount of time required to create fossil fuels makes them **non-renewable resources**—only a finite quantity is available. **Renewable resources** include things like wind, sun, plants, and other naturally replenished resources. Even more problematic is that plastic (even most bioplastic, which is made from renewable materials like corn and soybeans) does not **decompose**, so it will stay in a landfill for centuries. This is where recycling comes in. In fact, one ton of recycled plastic can save up to 2,000 gallons of gasoline.[7]

Dan Peterman has been working in "**adaptive reuse**" for many years. Adaptive reuse means rehabilitating a found object that some would consider trash into something functional. For instance, Peterman has transformed shopping carts into chairs and trash containers into kiosks and bike stations.[8] Peterman criticizes the wastefulness and neglect involved in trash production, favoring instead the imagination and beauty of recycling, reprocessing, and adaptive reuse. *Accessories to an Event*, much like Peterman's other artworks, exists in public spaces, sparking conversation, allowing interaction, serving functional purposes, and prompting people to reflect on social, civic, and ecological responsibilities.[9]

Dan Peterman, *Accessories to an Event*, 2006. Postconsumer reprocessed plastics and stainless steel hardware. Mildred Lane Kemper Art Museum, Washington University in St. Louis. University purchase, Bixby Fund, and with funds from the Weil Family, 2006.

Discussion Questions: What adjectives would you use to describe the texture of the sculpture? What is recycling and why is it important? Can you think of other examples of adaptive reuse or upcycling? Notice the pattern Peterman has created—how do the different parts of the sculpture work together? How does the sculpture function as an "accessory to an event"?

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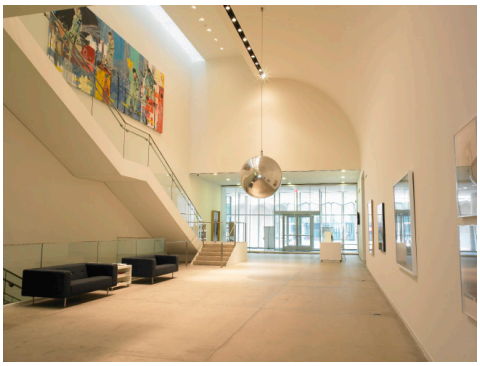
[2] http://www.musee-rodin.fr/en/collections/sculptures/three-shades
[3] http://www.vam.ac.uk/content/articles/s/bronze/
[4] http://www.vam.ac.uk/content/articles/a/rodin-working-methods/
[5] http://science.howstuffworks.com/plastic1.htm
[6] http://www.venocoinc.com/community/learning/primarypetrol.pdf
[7] http://www.ehow.com/about_4572206_why-recycling-important.html#ixzz2TULqwyPn
[8] http://www.thefreelibrary.com/_/print/PrintArticle.aspx?id=125918104
[9] http://www.artdaily.org/index.asp?int_sec=11&int_new=57653#.UVtcbhfBPwk



Olafur Eliasson, *Your Imploded View*, 2001. Polished aluminum, 51 3/16". Mildred Lane Kemper Art Museum, Washington University in St. Louis. University purchase, Parsons Fund, 2005.

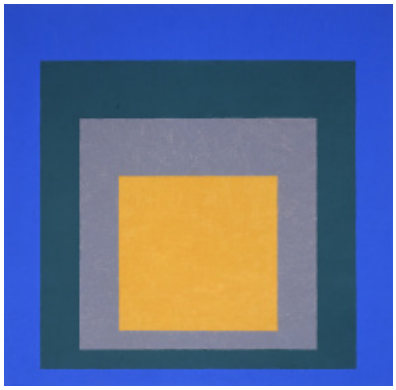
Olafur Eliasson, *Your Imploded View* (2001)

Your Imploded View, commissioned specifically for the Kemper Art Museum, is a kinetic sculpture made of cast aluminum and weighing 660 lbs. During installation, engineers conducted load tests to ensure that the structure of the building and all parts of the system (cable, hooks, bolts, etc.) could support it. The artwork can swing, so the engineering/artist team determined that the sculpture should not **oscillate** beyond a maximum **amplitude** of 3m. Oscillation refers to the repeated motion of a physical body along the same path. Amplitude refers to the distance between resting and the object's most distant point of motion. When this sculpture is pushed, but not yet moving, it possesses **potential energy**. When it is released and in motion, it possesses **kinetic energy**. In other words, potential energy is the stored energy an object possesses as a result of its position, and kinetic energy is the energy an object possesses as a result of its movement.[10]

Discussion Questions: What does the sculpture remind you of? How does the movement of *Your Imploded View* compare to that of *Five Rudders*? How do the shape and appearance of the sculpture affect your perception of the artwork and the Museum? What properties of aluminum make it a good medium for this sculpture?

Josef Albers, *Homage to the Square: Aurora* (1951-55)*

Josef Albers painted more than 1,000 canvases like this one, depicting either 3 or 4 nesting squares of different colors with the goal of methodically examining color, particularly the interaction of colors. He meticulously documented the exact pigments, brands, varnishes, and grounds on the back of each canvas, leading to the production of his iconic book on color theory *Interaction of Color*. Essentially, he was practicing the **scientific method**, which emphasizes gathering of evidence, questioning, and sound experimentation. The composition of nesting squares evolved from mathematical principles related to balance and unity, and remained a constant variable throughout Albers's experimentation with color.[11]

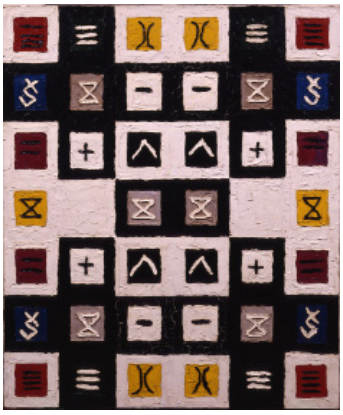


Josef Albers, *Homage to the Square: Aurora*, 1951–55. Oil on masonite, 40 1/8 x 40 1/2". Mildred Lane Kemper Art Museum, Washington University in St. Louis. University purchase, Bixby Fund, 1966. Copyright: Artists Rights Society (ARS)

His work relates to the science of vision, which is part biology and part psychology. Albers investigated the objective and subjective perception of color, noticing that variations in hue and tone affected the appearance of depth and movement on a flat surface.[12] In objective terms, color is received in the human eye via electromagnetic frequiences in the visible-light range. Vision requires a source of radiant energy, like a light bulb; a medium through which that energy travels, like water; and an object that absorbs and reflects different portions of the light spectrum, like an apple.[13] The **cones** and **rods** in the **retina** of the eye take in the reflected light and the **optic nerve** carries visual information to the **visual cortex** of the brain, where the experience of color is made conscious and human emotions, associations, and memory are generated.[14]

Discussion Questions: Do you see more warm or cool colors in *Homage to the Square: Aurora*? What about any primary or secondary colors? Do you perceive depth in the painting? What emotions, places, or other things do you associate with the colors in this painting? How would the painting change if any of the colors were different—if orange replaced green, for instance? Do you think Albers created a good experiment to test the interactions of color?

[10] http://artsedge.kennedy-center.org/~/media/ArtsEdge/LessonPrintables/grade-5/alexander_calder_mobiles_lever_worksheet_2.ashx
[11] http://americanart.si.edu/collections/search/artist/?id=46
[12] http://www.moma.org/collection/artist.php?artist_id=97
[13] http://www.artic.edu/aic/education/sciarttech/global_pages/g4.html#cone
[14] http://www.artic.edu/aic/education/sciarttech/2c1.html



Alfred Jensen, *Great Mystery I [Chinese Origin of the Decimal System! External Placement.]*, 1960. Mixed media on canvas, 50 x 42". Mildred Lane Kemper Art Museum, Washington University in St. Louis. Gift of Mr. and Mrs. Richard K. Weil, 1963. Copyright: Artists Rights Society (ARS)

Alfred Jensen, *Great Mystery I [Chinese Origin of the Decimal System! External Placement.]* (1960)*

This painting draws inspiration from ancient Chinese philosophy and knowledge systems—the symbols you see are actually numbers in ancient Chinese writing. The painting is composed of four Lo Shu diagrams, the oldest known example of a magic square, using figures one through nine, written in ancient Chinese characters, in a three-by-three grid in such combinations that the sum of each vertical, horizontal, and diagonal line adds up to fifteen.[15] The painting also draws on the ancient Chinese belief in harmonious opposites, for instance that **odd numbers** are heavenly numbers and **even numbers** are earthly numbers. The odd numbers are painted on a black background, the even numbers are painted on a white background. The character for five occupies the central location in each of the four Lo Shu diagrams.

Discussion Questions: Do any of these symbols look familiar? Do you notice any patterns or symmetries? Jensen was inspired by this ancient mathematical diagram—what other mathematical concepts could an artist use to create art?

Art Conservation

Art conservation means working to protect, preserve, and restore works of art. Art conservators are like detectives and scientists, searching for clues and testing hypotheses. They use tools like **microscopes**, **magnifying glasses**, **mass spectrometers**, and **x-ray machines** in addition to art materials like paint and paint brushes. An **x-radiograph** of a painting creates an image based on elemental properties of materials used and thickness of paint, allowing conservators to look at what is underneath the top layer of paint and to learn more about the materials and the artist's process.[16] Sometimes, conservators also remove tiny cross sections of paint to analyze the materials and process.[17] The cardinal rule of conservation is never to do anything to an artwork that you can't undo—so conservators must be very careful to thoroughly test for any potential damage. Scientific advances and technology allow conservators to determine how certain materials will react with each other and therefore how best to repair or protect an art object.

A conservation scientist at the National Gallery of Art examines a sculpture.

Discussion Questions: Look closely at artworks in the Museum. Can you see how they were made and what they were made of? Can you figure out how old an artwork is without looking at the label? How might a particular artwork change in the next 200 years? 500 years? Define **conservation**, **prevention**, and **restoration**. See the "Resources" section for more information on art conservation.

After you visit

Natural Paints: Create your own natural paint-making experiment to find out more about pigments, mediums, and the paints they create: http://webexhibits.org/pigments/index.html.

Kinetic Sculpture: Create your own kinetic sculpture modeled after Calder's and Eliasson's art-making processes. http://www-tc.pbskids.org/designsquad/pdf/parentseducators/ds_pe_ed_guide_unit3.pdf

Experiment with Color Mixing: Experiment with additive vs. subtractive mixing using light, colored filters, and paint. http://www.artic.edu/aic/education/sciarttech/2d3.html

The Relativity of Color: Who says Josef Albers is the only one who can play with color? See how colors interact with one another in this cut-paper activity: http://www.artic.edu/aic/education/sciarttech/2c1.html

Bronze Casting: Need to see it to believe it? Watch how a wax model becomes a bronze sculpture: http://www.youtube.com/watch?v=gVe3VeQfyzw and http://www.prometheusart.com/links.php?51186#.Uflg9I2cfl5

[15] Manchada, Catharina. *Models and Prototypes*, (St. Louis, MO: Mildred Lane Kemper Art Museum, 2006), 20-21.
[16] http://www.artic.edu/aic/education/sciarttech/2e1.html
[17] http://www.artic.edu/aic/education/sciarttech/2e3.html

Experiment with Pendulums: What would happen if the cable holding Eliasson's sculpture was shorter or longer? http://www.pbslearningmedia.org/resource/phy03.sci.phys.mfw.zpendulumint/virtual-pendulum/; http://ninenet.pbslearningmedia.org/resource/phy03.sci.phys.mfw.zpendulum/experimenting-with-a-pendulum/

Conservation: Conservators have to know a lot about art and science to conserve an artwork. Learn more about their process: http://ninenet.pbslearningmedia.org/resource/83ff20de-c469-4646-9d6a-550ac8e9d711/conservators-of-the-fine-arts-museums-of-san-francisco-visual-arts/

Creative Science: Steampunk brings creativity, science, and innovation together with a Victorian twist. See some steampunk inventions and make your very own. www.mwilsonlearninghub.com/emerson-steampunk-elective.html and http://www.amazon.com/How-Draw-Steampunk-illustrating-Underground/dp/1600582400

Afterimage Experiment: Do mine eyes deceive me? Well, they do, sort of... it's called an afterimage, and here's why it happens: http://www.unmuseum.org/exafter.htm

Resources

Print

Albers, Josef. "A Note on the Arts in Education." *American Magazine of Art* April 1936: 233. http://www.albersfoundation.org/Albers.php?inc=Bibliography

Albers, Josef. *Interaction of Color.* New Haven, CT: Yale University Press, 1963.

Kemp, Martin. *Visualizations: The Nature Book of Art and Science*. Berkeley: University of California Press, 2000.

Lipman, Jean. *Alexander Calder and his Magical Mobiles*. Easthampton, MA: Hudson Hills, 1981.

Livingstone, Margaret. *Vision and Art: The Biology of Seeing*. New York: Harry N. Abrams, Inc., 2002.

Marsocci, Joey and Allison DeBlasio. *How to Draw Steam Punk*. Irvine, CA: Walter Foster Publishing, 2011.

Online

More Science & Art resources: http://www.getty.edu/education/teachers/classroom_resources/curricula/art_science2/downloads/resources.pdf

Gravity: http://ninenet.pbslearningmedia.org/resource/idptv11.sci.phys.maf.D4KGRAV/gravity/

What is Color ?: http://new.livestream.com/WorldScienceFestival/WhatisColor & http://hyperallergic.com/130287/the-complications-of-color-as-explained-to-an-11-year-old/

Art Institute of Chicago STEM resources: http://www.artic.edu/aic/education/sciarttech/index.html

The STEAM Journal: http://thesteamjournal-inauguralissue.blogspot.com/; http://scholarship.claremont.edu/steam/

Artist/Scientist Arthur Huang: http://arts.gov/art-works/2011/art-talk-arthur-huang

Steam Punk: www.mwilsonlearninghub.com/emerson-steampunk-elective.html

Conservation Resources:

http://www.youtube.com/watch?v=DeP5KPEcKfY; http://www.youtube.com/watch?v=UeDG8XDt2mc

http://www.youtube.com/watch?v=ALxLQqPhTq4

http://www.artic.edu/collections/conservation/revealing-picasso-conservation-project/examination-techniques/x-radiography

http://www.livescience.com/13499-hidden-painting-features-xrays-110331.html

http://www.metmuseum.org/~/media/Files/Learn/Family%20Map%20and%20Guides/MuseumKids/What%20is%20Art%20Conservation.pdf

http://ninenet.pbslearningmedia.org/resource/83ff20de-c469-4646-9d6a-550ac8e9d711/conservators-of-the-fine-arts-museums-of-san-francisco-visual-arts/

* Please note that this artwork is not always on view. If this is the case, the staff will substitute a suitable artwork.

All artworks are in the collection of the Mildred Lane Kemper Art Museum at Washington University in St. Louis.