LOS ANGELES COUNTY MUSEUM OF ART
5905 WILSHIRE BOULEVARD
LOS ANGELES, CALIFORNIA 90036
EDUCATION DEPARTMENT

LACMA

BUILDING STEAM: ART, MATH, AND TECHNOLOGY

MICHAEL HEIZER
United States, b. 1944
Levitated Mass, 2011
Granite, concrete, and steel; 258 x 5472 in.
Zenith: 180 in., Weight: 340 tons
LACMA © Michael Heizer (M.2011.35)

STEM (science, technology, engineering, and math) Education may be a newly named initiative, but these content areas have always been at the core of the K–12 curriculum. As soon as the acronym "STEM" was conceived, artists and museums raised the issue of where the arts come into play, expanding the initiative to "STEAM." STEAM and its application to K–12 classrooms highlight the relationship between artistic, mathematical, and engineering practice. Artworks from the collection of the Los Angeles County Museum of Art can provide the basis for lesson plans that have the potential to broaden student thinking in all of these subjects. The key question addressed in this packet is: How do artists connect math, engineering, and technology to make art? This curriculum connects initiatives that cross into the museum and the classroom by placing artworks in conversation with what are often considered "hard" subjects.

PROJECT-BASED LEARNING

Just as STEAM is a newly named initiative that revisits older ideas in a contemporary way, Project-Based Learning, or PBL, is a reconception of longstanding pedagogy in a project-based approach. The units included here are presented in this format, and each is formulated to support student inquiry in math and engineering through the language of the visual arts and principles of design.

Educators have long valued teaching that emphasizes *learning while doing* in contexts inspired by real-world situations. PBL supports this philosophy by placing the student at the center of his/her own learning, empowering students to propose questions, direct research, and interpret answers. The educator acts as a guide through exercises in exploration, experimentation, revision, and reflection. The process is the focus, rather than the culminating project, which requires educators to relinquish some control over the end product. Teachers learn alongside students as they cooperatively define the project, utilizing a combination of direct instruction and open-ended questioning.

In PBL, teaching and learning take the form of an extended experience comprising key tenets.

Point of Entry: An introductory activity such as a field trip, discussion, or demonstration that can be inspired by literature, journalism, media, or art.

Essential Question: A driving question that frames the unit and guides student thinking throughout the process.

Core Content: Curricular concepts that integrate learning across subject areas.

Line of Inquiry: A series of open-ended questions that navigate exploration of the essential question and practice with core content. Stages include brainstorming, mapping of tasks, and generating possible solutions.

Equal Voicing: Various roles (chosen by either the student or the educator, depending on age or learning needs) that provide opportunities for individual and collaborative contributions.

Revision: Editing prompts to encourage adjustments in research or improvements to the final product.

Presentation: A forum that allows students to share their research with classmates, the school, the neighboring community, or practitioners in the field.

Reflection: Students state their accomplishments through formative assessment and cumulative self- or group-evaluation. Reflection recalls the use of problem-solving and persistence.

The artworks featured in this curriculum serve as engaging entry points into math and engineering concepts. Use the information and images provided to facilitate an initial conversation or interaction with an artwork through questions such as, “What do you see?” “What do you see that makes you say that?” and “What more can you find?” The essential questions that follow serve as extensions into PBL experiences, and, in this case, students should utilize the languages of mathematics and the visual arts to answer such questions. Suggested grade levels are aligned with content standards that can be scaffolded and adapted for students.

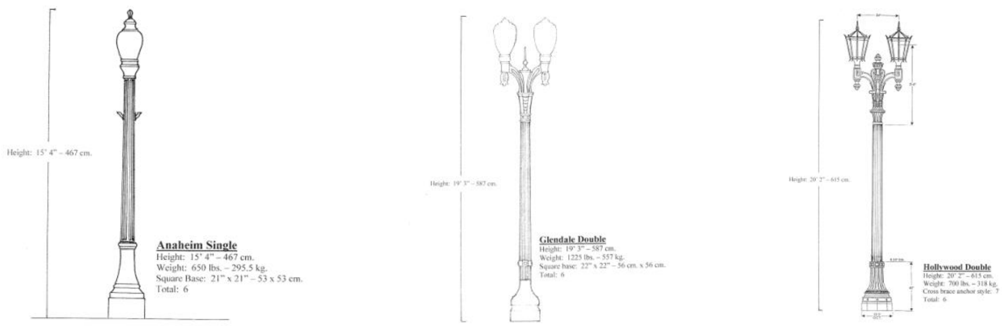
Urban Light, 2008, Chris Burden

CHRIS BURDEN
United States, b. 1946
Urban Light, 2008
202 restored cast-iron antique street lamps, 320 1/2 x 666 1/2 x 704 1/2 in.
LACMA, the Gordon Family Foundation's gift to Transformation: The LACMA Campaign
© Chris Burden (M.2007.147.1–.202)

ARTWORK IN FOCUS

Chris Burden, an L.A.-based artist interested in contemporary life and the urban experience, has spent much of his career exploring the intersection of art and engineering, employing construction materials and found objects to create large-scale sculptures such as *Urban Light.* For *Urban Light,* Burden utilized a collection of 202 antique street lamps from the city of L.A. circa the 1920s and '30s. Their installation, arranged carefully on a grid, exemplifies the real-world nexus of math, art, and design.

The lights that populate this work were collected over a seven-year period, and each individual lamp represents the unique time and place of its original location. For example, the seventeen lamps from Lynwood are each twelve feet tall and simple in design, with a single light globe. The six from Glendale stand at nineteen feet and feature double globes and a decorative design. All 202 lamps have fluted shafts or trunks in the form of prisms, and all are painted grey. The street lamps are grouped in rows according to neighborhood, and the arrangement forms a grid that (despite initial appearances) is not perfect—but does offer repetition of shape and color.



CHRIS BURDEN
United States, b. 1946
Diagrams of Urban Light, 2007

PROJECT: DESIGN AN URBAN GARDEN

Point of Entry: Planning for the sculpture's installation paralleled the planting of a garden. The lampposts were first measured for height, weight, and square base. Similar to how one might organize flowers, the artist grouped the lamps according to their unique designs, such as single, (symmetrical) double, or (rotationally symmetrical) triple globes. Rows were arranged by height. The tallest posts comprise the middle section and are flanked by the shortest posts to create the effect of a symmetrical pyramid. From the perspective of the street, this allows the viewer to see all of the lamps at once. In the practice of gardening, a similar arrangement ensures that the shortest and tallest plants receive equal amounts of light.

Essential Question: How can you use symmetry and scale to beautify the school?

Grades: K–4

Core Content: Line, shape, pattern, motif, form, scale, polygonal prism, symmetry (bilateral and rotational), algebraic expression, and space.

Line of Inquiry: What do you see in *Urban Light*? When you look closely, what shapes, patterns, or motifs do you notice? How would you describe the bases and columns in geometric terms? When you take an overall view, what type of lines emerge? How does the sculpture's arrangement form a two-dimensional grid and a three-dimensional pyramid? How are the lampposts grouped? How many globes do you see in each group? Write an algebraic expression to describe the total number of globes (y) as it relates to the number of lampposts (x). Use a coefficient of 1, 2, or 3 to distinguish single-, double-, and triple-globed posts. If you were to design a school garden inspired by this artwork, how would you map the arrangement of flowers and plants, and why?

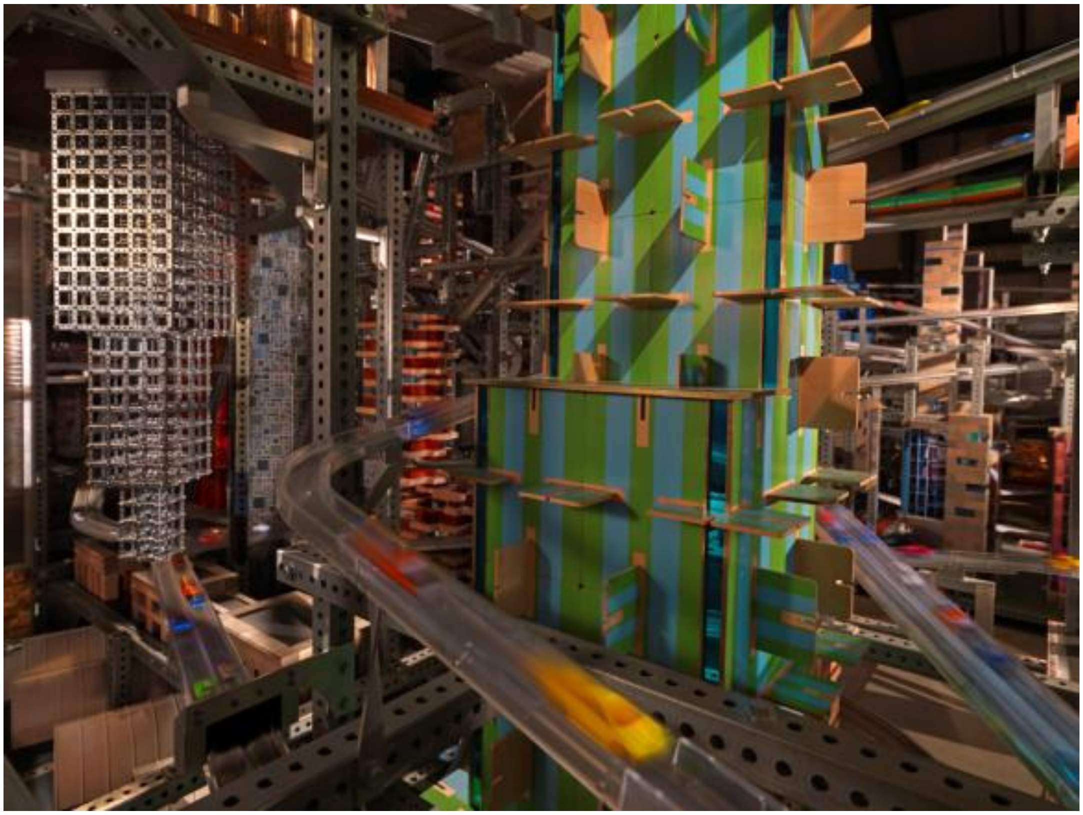
Equal Voicing: How will you work in teams to execute the garden? Students may take roles: botanists to research plants and their characteristics; mathematicians to determine the distance between two plants and where seeds should be planted by plotting the plants on a grid; and, finally, gardeners to realize the design.

Revision: What other ways could you group the plants? How can you arrange them so that they all receive equal amounts of sunlight? Where on campus will you plant the garden? How much space will it require?

Presentation: Unveil the gardens in a ribbon-cutting ceremony for the school. Present your research, such as information on the various garden habitats, at an accompanying science fair. Ask students to present their findings to classmates and peers.

Reflection: How do people practice math in everyday life? What is the relationship between math and design? If you were to design the garden again, what parts of the process would you repeat? What would you do differently, or what changes would you make? Where could you plant another garden?

Metropolis II, 2010, Chris Burden



CHRIS BURDEN
United States, b. 1946
Metropolis II (detail), 2010
3½ hp DC motors with motor controllers, 12,000 custom manufactured die-cast cars (1,100 for operating, 10,900 for replenishing damaged cars), 26 HO-scale train sets with controllers and tracks (13 for operating,13 for replenishing damages), steel, aluminum, shielded copper wire, copper sheet, brass, various plastics, assorted woods and manufactured wood products, Legos, Lincoln Logs, Dado Cubes, glass, ceramic and natural stone tiles, acrylic and oil-based paints, rubber, and sundry adhesives; 117 x 339 x 230 in.
© Chris Burden. Courtesy Gagosian Gallery. Photography by E. Koyama. (L.2010.33.1)

ARTWORK IN FOCUS

In addition to large-scale objects, Burden is also an avid collector of miniatures, and has employed them to create imaginative works such as *Metropolis II.* A model city composed of cars, trains, and buildings, *Metropolis II* is a maze of speed and sound. Eleven hundred Hot Wheels-size cars and thirteen miniature passenger trains race through 1,350 feet of track. Twenty-five skyscrapers dot the horizon, interwoven with two freeway ramps and eighteen lanes of traffic.

The energy starts at the center of the sculpture, where the conveyor belt magnets carry six lanes of cars to a seven-and-a-half foot peak. The cars are lined up in rows, and each follows a distinct and specific path. Attempting to follow a single car with the eye can be dizzying; if they were full-size cars they would be traveling at 240 miles per hour.

ZAK COOK
United States, b. 1969
Map of Metropolis II, 2010

PROJECT: BUILD A MODEL CITY

Designer Zak Cook worked with Burden and a team of artists to build *Metropolis II.* The planning phase, mapping, was accomplished with simple string and pen. The sculpture's footprint, or overall length and width, were first determined based on the dimensions of the magnetic conveyors. A core base was mapped out at seven by twenty-two feet to scale. Designers added extensions and corners to the basic rectangular shape to alter the direction of the cars' eventual travel routes. In terms of dimensions, special consideration was given to the fact that the final sculpture would not remain in Burden's studio and would need to be shipped—and likely many times—to exhibition sites. Cook decided where the different parts of the base would separate, creating seam lines so that all parts would be removable and replaceable for both assembly and disassembly. Within the footprint, Cook mapped out a series of track configurations using colored string to code track groupings. The goal of mapping the tracks was to maximize the number of tracks that could assemble onto the two-dimensional footprint, considering the width of track groupings as outer tracks would be longer and the inner tracks shorter. Designers also mapped both right and left curves to create balance in the overall direction of travel. Finally, the string tracks were marked with pen at five-foot-scale increments to help the artists transform a two-dimensional representation into a three-dimensional sculpture.

The boxes that would eventually transport the sculpture were seven and a half feet tall, so Cook set the maximum height of the sculpture at seven and a half feet. With the tallest peak in mind, he experimented with the slope of the tracks and figured that a slope of five and a half degrees would produce an ideal speed. Cook used the Pythagorean theorem to determine the width of construction (one and one-eighth feet of fall per linear foot of travel), and artists built to this dimension. Designers worked out individual curves using curve templates, and track walls were beveled by hand for fluid travel. They tested the cars on the tracks, placing brushes before and after significant curves to avoid crashes. Lastly, the support structure was "sketched out" by positioning metal frames in different combinations. Cardboard mockups of buildings were added in as layers, and final buildings took the form of wooden replicas (and one paper original) of the children's game House of Cards by 1950s designers Charles and Ray Eames, as well as tiled ceramic, mirrored, and metallic buildings.

Point of Entry: The relationship between the sculpture's vehicles, roads, and buildings and the process the artist went through to create it resemble a city-planning experiment. City planners use design principles and engineering tools to create environments that connect people with buildings, transportation, and the surrounding urban landscape. With technology, they create designs that impact the real world. Use accessible and recyclable materials to create your own classroom city.

Essential Question: How do artists and designers practice engineering in everyday life?

Grades: 4–8

Core Content: Length, height, and width; square footage; cubic feet; ratio; slope; radius; and velocity.

Line of Inquiry: What is the first thing you notice about *Metropolis II*? What do you find following a closer look? Does the sculpture look like a representation of the past, present, or future? What do you see that makes you say that? Describe the size of the work and the speed of the cars.

What impact does a model version like this have on the "life" of the city? What types of vehicles, buildings, and infrastructure would you include in your own unique city? For what purposes and functions? How would they be used in relationship to one another?

Determine the footprint of your classroom city, starting with a simple rectangular shape. Map roads using string. Determine a ratio for taking measurements to scale, and mark intervals on the map accordingly. Using marbles as vehicles and cardboard (folded in a V shape) or pipe insulation (cut in half for a U shape) as roadways, experiment with dropping the "cars" onto the track.

How can you alter the tracks to control the speed of travel? Map the course of the track on a coordinate plane. Now, how will you transform a two-dimensional map into a three-dimensional city?

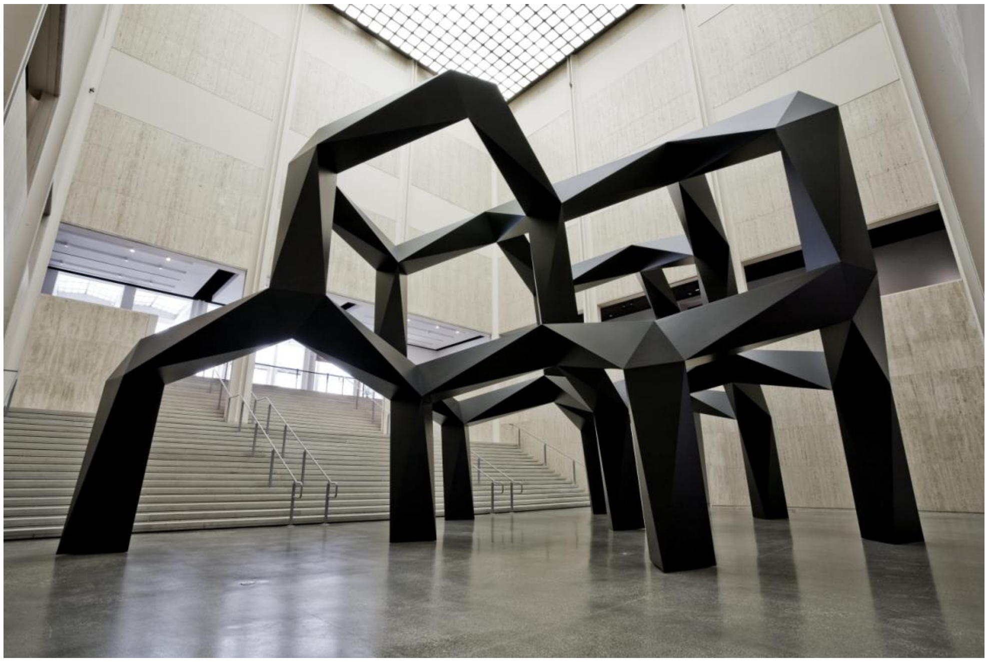
Equal Voicing: How will the class work together to build the city? Assign roles that include city planners to map the space, engineers to design the roadways, architects to imagine mixed-use structures, and mathematicians to help preparators take the map to scale.

Revision: Where will the support structures go? How should they be configured and why? Where do marbles fly off the tracks? Reduce the angle of descent to slow the rate of travel, or add a textured material such as brushes to slow the marbles at key trouble spots. Finally, how will you layer buildings into the structure for aesthetic effect? What household and recycled materials will you source to construct the buildings?

Presentation: Conduct a series of test runs in the school auditorium for lower-grade audiences. Present a series of accompanying poster boards that scaffold the construction process down into digestible steps comprehendible for younger students. After receiving feedback from students and teachers, invite local engineers and city planners to a special viewing. Ask groups of students to talk about how the creators' different roles contributed to the overall process.

Reflection: What are the real-world professions that practice design and engineering? What are the paths of study and entry points into the field? How do these jobs require creative and collaborative thinking similar to the artistic process?

Smoke, 1967, Tony Smith

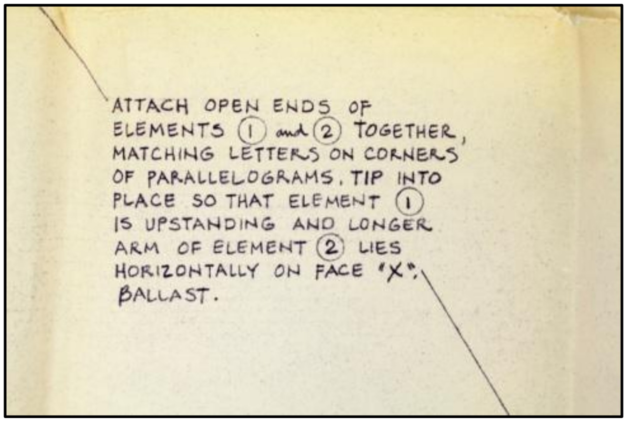


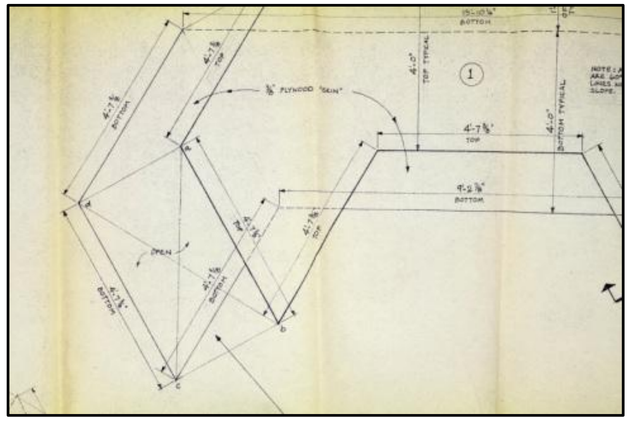
TONY SMITH
United States, 1912–1980
Smoke, 1967, fabricated 2005
Painted aluminum, installation; 290 x 564 x 396 in.
LACMA, made possible by the Belldegrun Family's gift to LACMA in honor of Rebecka Belldegrun's birthday
© Tony Smith Estate/ARS, NY (M.2010.49)

ARTWORK IN FOCUS

During the 1960s and '70s, Tony Smith's architectural artworks helped define "minimalism" in modern sculpture, which was concerned with simplicity rather than ornamentation. Many of his sculptures employ the triangle in complex geometric patterns. In the sculpture *Smoke,* in LACMA's permanent collection, two basic triangular units, a tetrahedron (a polyhedron or three-dimensional solid made of four triangular faces) and an octahedron (formed by two tetrahedrons opened at a vertex and conjoined), are scaled to life size, repeated, and combined in a methodical configuration. While the design is strictly pre-scribed, the sculpture's outline seems organic, appearing curvilinear and growing both taller and wider, akin to the multidirectional path of billowing smoke as the viewer walks toward it, beneath it, and views it from above.

The individual parts of *Smoke* are machine-made, but their configuration references shapes and forms inspired by life, such as a crystalline structure. The overall hexagonal formation mimics the shape of a honeycomb and points to Smith's fascination with natural enclosures.[1] As with a cave, both positive and negative space serve defining roles. The patterned absences or gaps in space define the sculpture's environment as much as the solid portions. Perhaps this is why Smith called his works "presences" rather than sculptures, emphasizing the relationship between an artwork and its surrounding environment in the creation of a multidimensional experience.





TONY SMITH
United States, 1912–1980
Diagram of Cigarette, 1967

PROJECT: SCULPT A GEOMETRIC PATTERN

The tetrahedron and octahedron (an eight-faced polyhedron) are modules, or basic units, that dominate much of Smith's practice. "In my work," he explained, "I use small cardboard maquettes [models], actual little tetrahedra and octahedra, and I paste them together with tape in order to arrive at the form of the work."[2] By rearranging the modules in various combinations until he reached a desired spatial effect, Smith not only determined the overall form but the ratio between the two parts, such as three tetrahedra to every two octahedra. The ratio presumably created a system for production that informed the execution of the final work.

Smith explored this building process in a nearly thirteen-foot-tall "cave" constructed of three thousand die-cut tetrahedra and fifteen hundred octahedra-shaped pieces of corrugated cardboard. For the sculpture's installation, the cardboard die-cuts were shipped flat to the installation site and individually assembled and adhered together according to Smith's model. This and other works made of expendable materials have since been destroyed. Some sketches, however, have remained, such as this diagram for another Smith sculpture titled *Cigarette.*

Point of Entry: Take a closer look at the diagram and chart the details that you see. How does it mark Smith's mathematical thinking and artistic process? Notice the overall form of the sculpture as well as the shape of the module. Each vertex is labeled a, b, c, or d, forming a system to direct the connection of angular points.

Essential Question: How do shapes combine to create sculptural forms inspired by life?

Grades: 6–10

Core Content: Shape, module or fractal, vertex, polyhedron, volume, ratio, form, geometric and organic, positive and negative space, maquette or model, scale, and weight.

Line of Inquiry: What do you notice about *Smoke*? Describe the basic unit that comprises this work. How is it repeated and arranged to create a pattern? If you added more units to the pattern, what would the progression of growth look like and where would the sculpture's outer limits expand? If you were to create a sculpture inspired by nature using a pattern, what form would you choose? Visit a local park for inspiration.

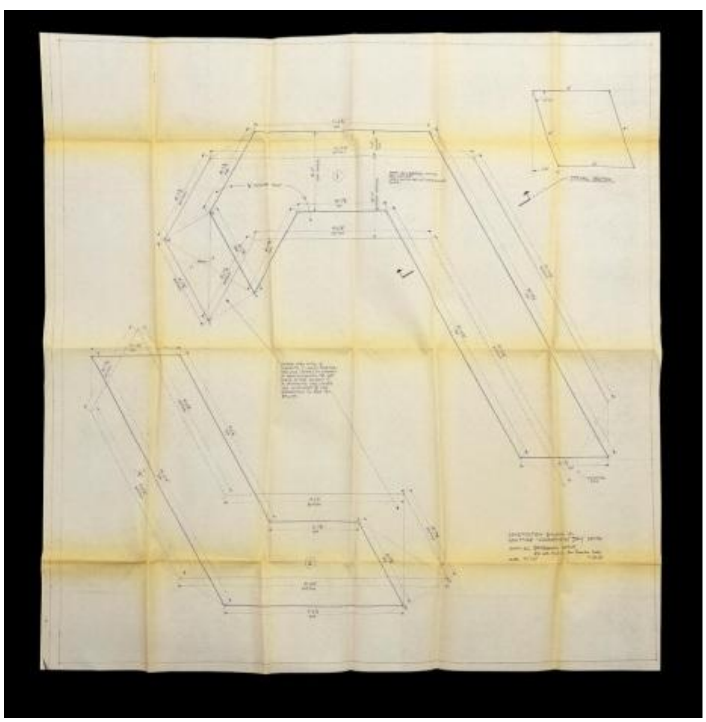
Sketch a shape, then bring the sketch to class. Examine the shape that you created and think about how you might divide the shape into a fractional representation. What is the basic unit that could comprise the overall form? How are the units joined? Is there a hidden shape at the junctures? Use toilet paper tubes or rolled newspaper as basic industrial units and experiment with construction. Determine the points of intersection and the secondary form (for example, a crumpled and compressed sheet of newspaper) that could be used to adhere two or more units at a vertex. As you build, count the ratio of primary to secondary units and document your plan as a blueprint.

Equal Voicing: How will you work as a team to create the sculpture? Roles may include mathematicians to measure the units, draftsman to draw the blueprint, engineers to design construction, and preparators to execute the design. Researchers should determine the cost of reproducing the paper units in metal, and accountants calculate the total cost of building a final version in metal.

Revision: If certain parts appear unstable, how will you alter the weight distribution or stress to secure the sculpture? If an alteration occurs to one piece, how will it affect other pieces? Revisit the location where the sculpture will be installed. Does it fit aesthetically with its surroundings? How much material will be needed to execute a final version of the sculpture in metal, and at what cost? Include financial findings on the blueprint.

Presentation: Request permission to install the paper sculptures in the local park for one day. Invite the city parks and recreation department to attend the opening, and ask students to present the blueprints as new artwork proposals. Ask department representatives to vote on the most successful proposal, based on aesthetics and production costs.

Reflection: Does math exist in nature? How do artists transform natural shapes into man-made forms? How do teams of people execute artworks? How do other creative practitioners, such as designers and architects, find inspiration in nature?



TONY SMITH
United States, 1912–1980
Diagram of Cigarette, 1967
© Tony Smith Estate

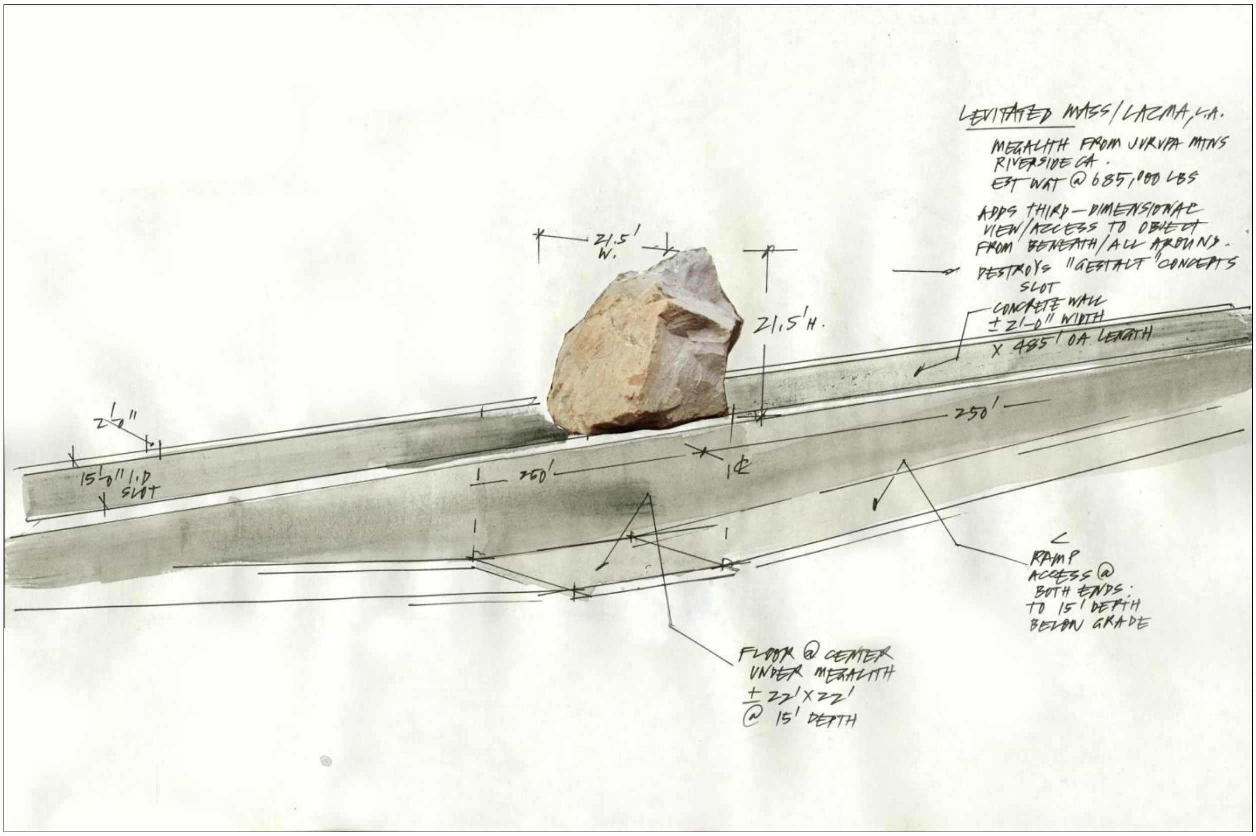
Levitated Mass, 2011, Michael Heizer

MICHAEL HEIZER
United States, b. 1944
Levitated Mass, 2011
Granite, concrete, and steel; 258 x 5472 in., Zenith: 180 in., Weight: 340 tons
LACMA © Michael Heizer (M.2011.35)

ARTWORK IN FOCUS

LACMA's newest installation, *Levitated Mass,* connects the fields of math and engineering with art. Its creator, Michael Heizer, had visited archaeological sites with his father, Dr. Robert Heizer, an archaeologist who studied the transport of megarocks during antiquity. The concept of ancient cultures using technology to mark their place and time undoubtedly influenced Michael Heizer, who is considered to be an early land artist. The land-art movement of the 1960s and '70s engaged the land as a sculptural material, and often located artworks in nature.

Levitated Mass was originally conceived in 1969, during the land-art movement, and realized in 2011, after the perfect rock was identified to serve as the artwork's specimen. The 340-ton piece of granite was transported 106 miles from its home in a Riverside, California, quarry to its new installation at LACMA. At a height of 21½ feet, the boulder sits along a 456-foot-long ramp cut into the museum's Hancock Park lawn at a total depth and width of 15 feet, which allows crowds to walk directly underneath the giant rock.



MICHAEL HEIZER
United States, b. 1944
Preliminary sketch for Levitated Mass, 2011
Courtesy of the artist © Michael Heizer

PROJECT: INSTALL A SITE-SPECIFIC SCULPTURE

When Heizer identified the pyramidally shaped rock, he inspected it and took detailed measurements. Construction workers used these dimensions to build the customized ramp out of concrete and reinforced steel, and designers used them to engineer the 294-foot-long, 32-foot wide by 23-foot-tall transporter to lift and carry the rock. To move the rock, workers first dug beneath all of its sides and used hydraulic jacks to lift it. Workers then assembled the carrier around the rock to form the foundation of the transporter. The carrier was designed with many pivot points so that various sections could move independently. Nearly the width of three freeway lanes, the boulder was driven at just five to eight miles per hour over eleven consecutive days.

When the rock arrived at LACMA, a custom-built crane lifted the rock into place. Granite landscaping and palm trees were added to reference its original desert home. A band of steel encircles the installation, marking a slope that slowly descends toward the ramp, giving visitors the opportunity to approach the rock from ground level and even touch its surface.

Point of Entry: *Levitated Mass* is an example of a site-specific installation, or an artwork in the form of an environment made with a particular location in mind. Take a look at Heizer's preliminary sketch. How did he consider the museum campus when planning for the installation? What evidence can you find to support your claim? Installation art often engages the viewer in a sensory experience. What might it feel like to walk underneath *Levitated Mass?* How would the experience change under a larger or smaller rock, or an entirely different object?

Essential Question: How do artists connect math, engineering, and technology to create sculptural installations?

Grades: 8–12

Core Content: Weight, displacement, balance, force, mass, density, volume, dimensions, gravity, distance.

Line of Inquiry: What surprises you about *Levitated Mass*? What questions do you have for the artist? For the mathematician or the engineer? How can you calculate the amount of force (mass multiplied by speed) required to move this mass a specific distance? Considering the amount of energy and coordination required to move the rock, what might the impact be of moving several rocks of this scale to a single location? What tools would be necessary for such transport?

Experiment with the transport of objects of varying weight and scale, from a marble to a gallon of water, a projector, a desk, or a television. What technology could aid in the transport process? How could you enlist the expertise of others? Choose a large-scale object that exists on your campus, such as an old bench or an unused bookcase. Consider where you might move this object, whether to the playground or the library. Calculate the distance it must travel and the force required to move it. Generate a list of technologies or resources needed for the transport. How will you prepare the new site? What will you add to transform this object and site into a functional art installation?

Equal Voicing: How will the class work as a team to install the object? Roles may include engineers to plan the transport, preparators to execute the installation, and sculptors to re-envision the surrounding environment to enhance the installation's look and feel.

Revision: Perhaps this object has previously gone unnoticed. How will students and teachers interact with it now? What will you need to enhance the object and site? Identify source materials that complement the look, feel, and function of your installation, such as books or seating to turn the old bookcase into an interactive library site.

Presentation: Invite members of the school, neighborhood, and professional community with whom students interacted over the course of the previous units to view the campus installations. Present the preliminary studies that informed the artwork.

Reflection: What are the similarities and differences between artistic, mathematical, and engineering practice? What is the value of each to society? Why is it beneficial for artists, mathematicians, and engineers to work together?

CLASSROOM RESOURCES

Use LACMA as a resource for your PBL instruction. Compare the images on the following pages with:

- twenty-four-hour video of *Urban Light* (included on the curriculum CD)
- a spotlight video of *Metropolis II* (http://lacma.wordpress.com/2012/01/10/metropolis-ii)
- time-lapse images of *Smoke's* construction (www.lacma.org/video/time-lapse-images-smoke)
- multimedia documentation of *Levitated Mass* to track the rock's transport (http://www.lacma. org/video/levitated-mass).

Consider launching your unit by visiting the museum with your class as an interactive entry-point activity.

When designing your own PBL units of instruction, consider using the brainstorming template and project calendar provided to plan and facilitate the experience. Research artworks from LACMA's permanent collection to serve as inspiration (www.lacma.org/art/collection). If you share students with another instructor, perhaps divide the work by pairing up with a colleague so that, for instance, the math teacher handles math instruction and the art teacher facilitates the art-making. Build in as many opportunities as possible to share student work with classmates, faculty, administrators, and the Education Department at LACMA.

WORKS CITED

1 Jane Livingston, "Tony Smith" in *A Report on the Art and Technology Program of the Los Angeles County Museum of Art, 1967–1971,* pp. 307–8.

2 Jane Livingston, "Tony Smith," p. 309.

These curriculum materials were prepared by Jennifer Reid, Kiffen Madden-Lunsford, George Crowder, and Holly Gillette and designed by Jenifer Shell.

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DEPARTMENT OF CULTURAL AFFAIRS City of Los Angeles

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Urban Light, 2008
202 restored cast-iron antique street lamps, 320½ x 666½ x 704½ in.
LACMA, the Gordon Family Foundation's gift to Transformation: The LACMA Campaign
© Chris Burden (M.2007.147.1–.202)

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Urban Light, 2008
202 restored cast-iron antique street lamps, $320\frac{1}{2}$ x $666\frac{1}{2}$ x $704\frac{1}{2}$ in.
LACMA, the Gordon Family Foundation's gift to Transformation: The LACMA Campaign
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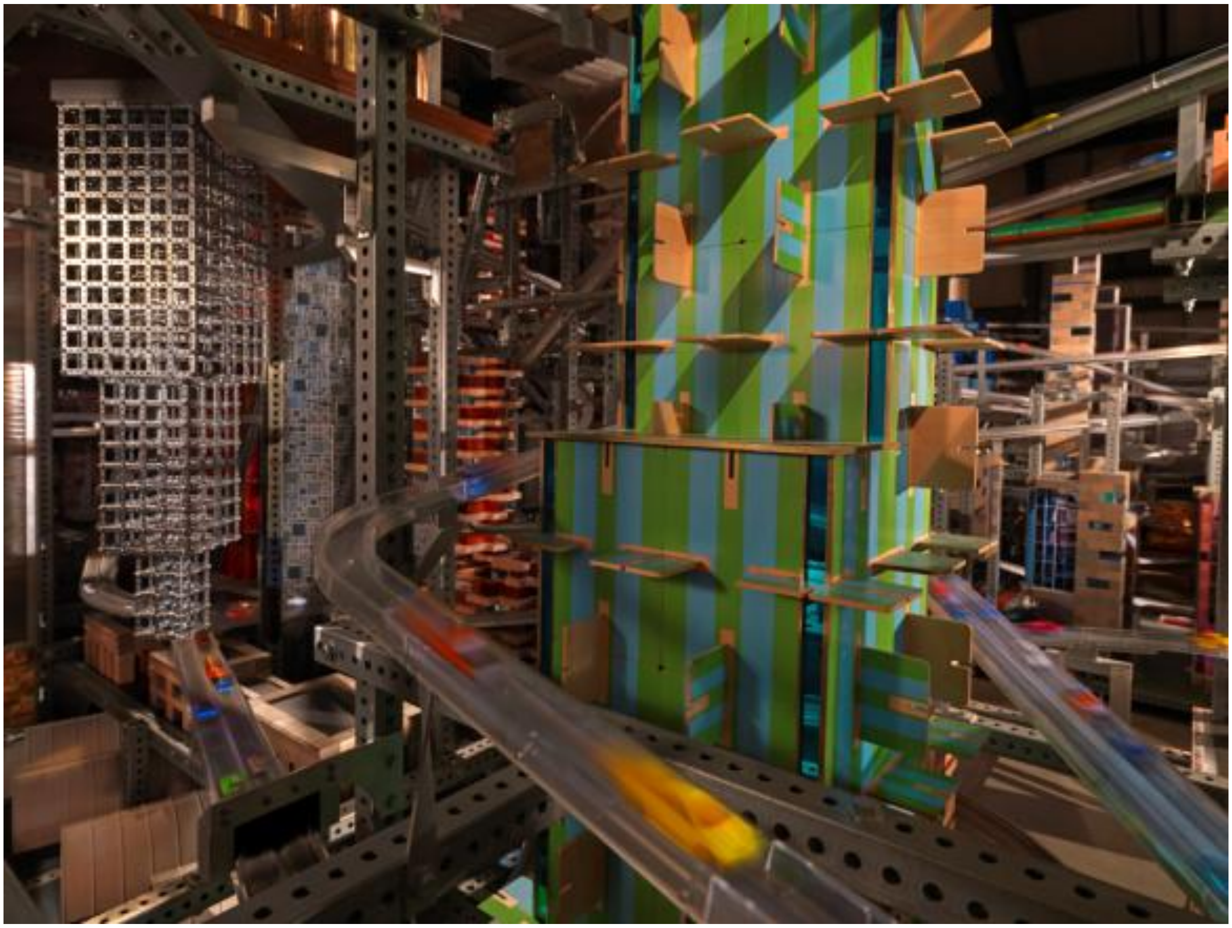

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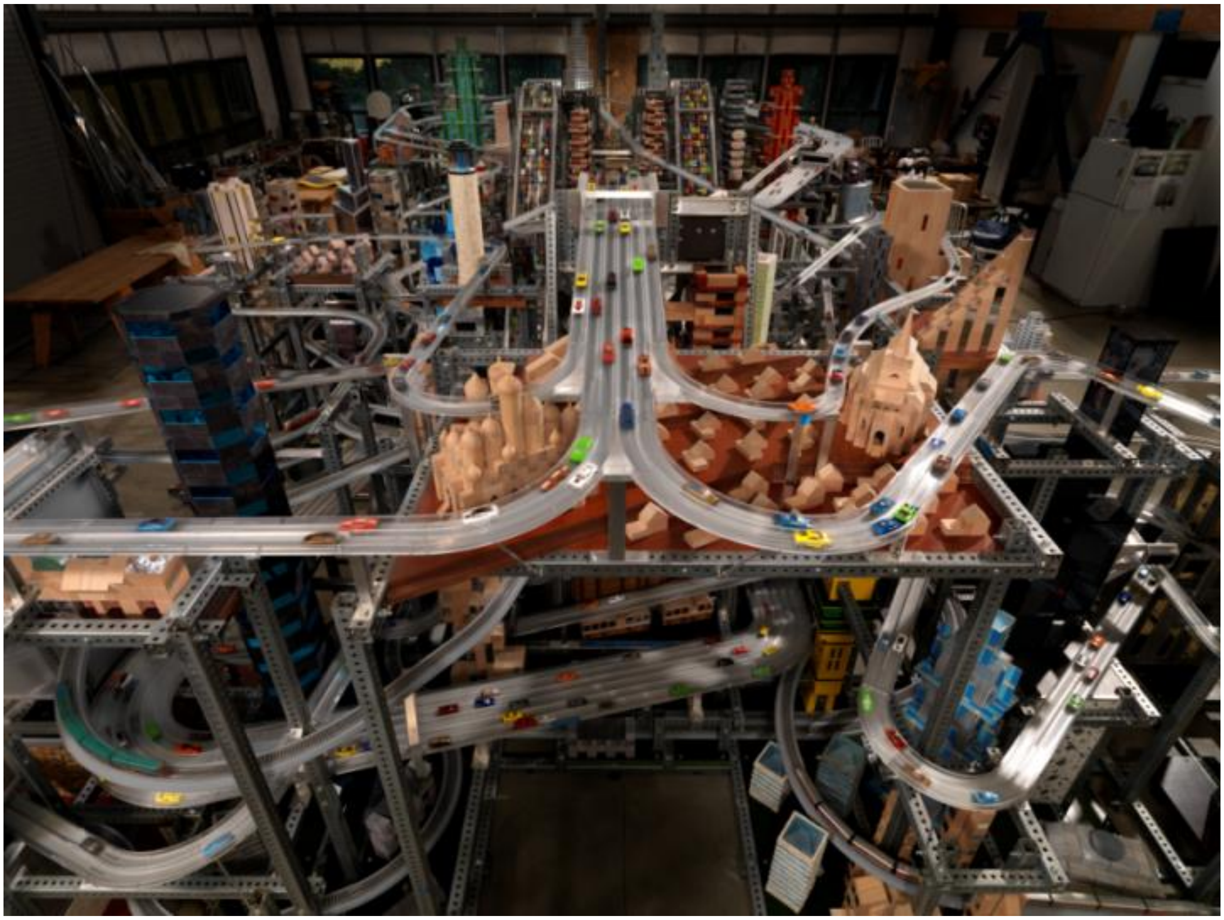

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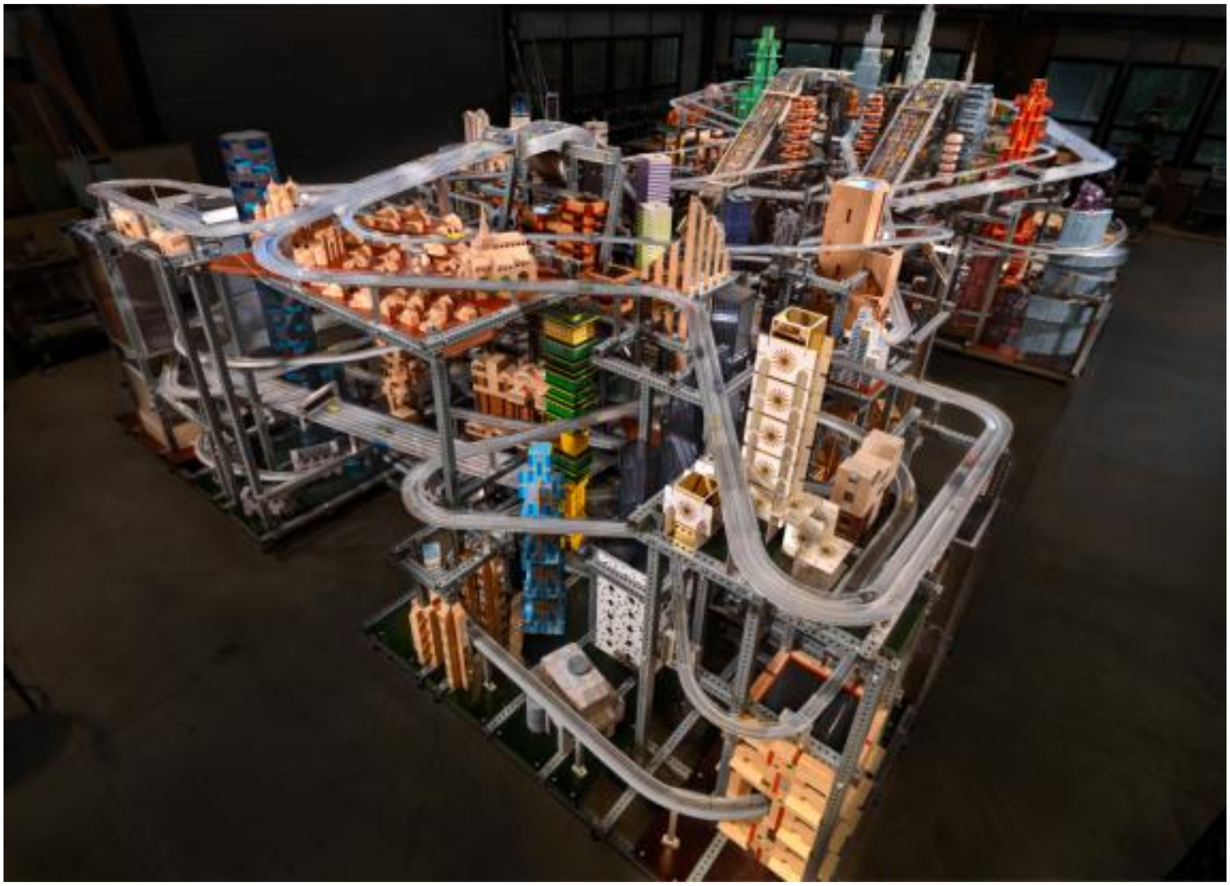
© Chris Burden. Courtesy Gagosian Gallery. Photography by E. Koyama. (L.2010.33.1)



CHRIS BURDEN
United States, b. 1946
Metropolis II, 2010
3½ hp DC motors with motor controllers, 12,000 custom manufactured die-cast cars (1,100 for operating, 10,900 for replenishing damaged cars), 26 HO-scale train sets with controllers and tracks (13 for operating,13 for replenishing damages), steel, aluminum, shielded copper wire, copper sheet, brass, various plastics, assorted woods and manufactured wood products, Legos, Lincoln Logs, Dado Cubes, glass, ceramic and natural stone tiles, acrylic and oil-based paints, rubber, and sundry adhesives; 117 x 339 x 230 in.
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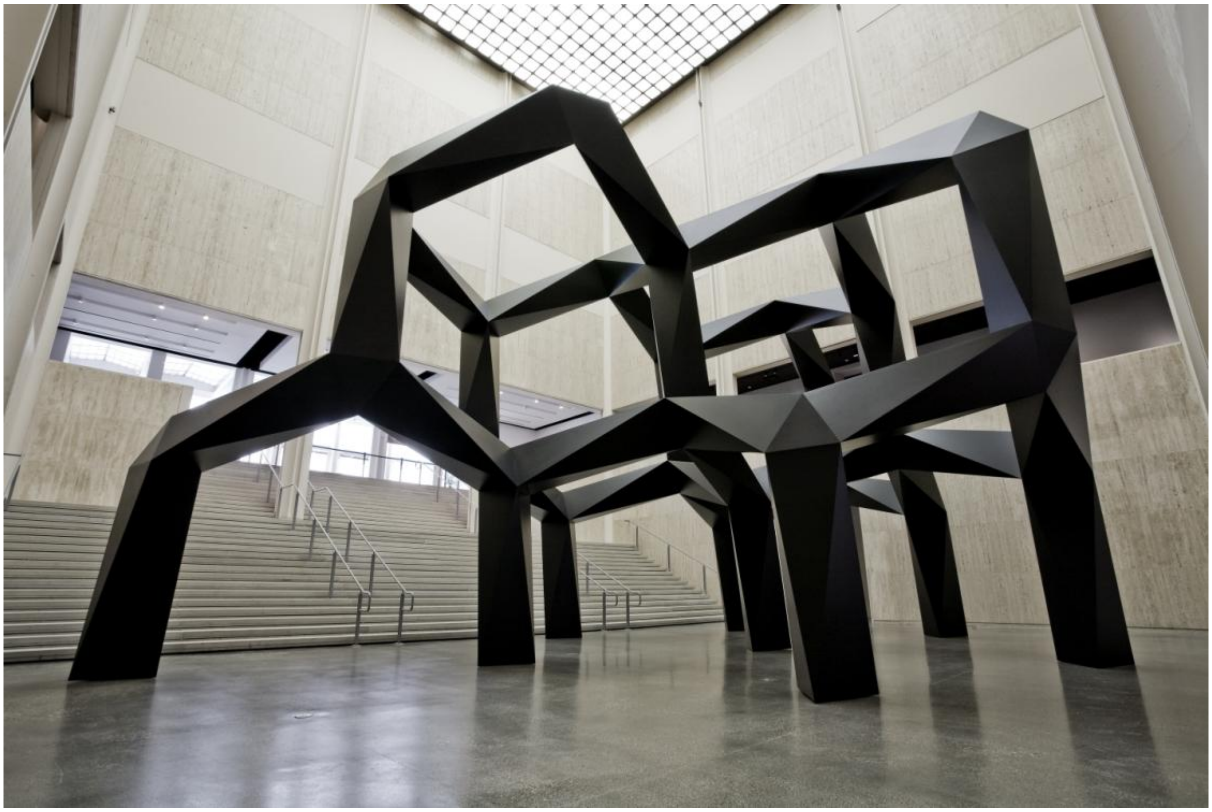

TONY SMITH
United States, 1912–1980
Smoke, 1967, fabricated 2005
Painted aluminum, installation; 290 x 564 x 396 in.
LACMA, made possible by the Belldegrun Family's gift to
LACMA in honor of Rebecka Belldegrun's birthday
 (M.2010.49)

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MICHAEL HEIZER
United States, b. 1944
Levitated Mass, 2011
Granite, concrete, and steel; 258 x 5472 in.
Zenith: 180 in., Weight: 340 tons
LACMA © Michael Heizer (M.2011.35)

MICHAEL HEIZER
United States, b. 1944
Megalith slated to become part of Michael Heizer's Levitated Mass, prepared for transport from quarry in Riverside County to the Los Angeles County Museum of Art, 2012
2012 © 2012 Michael Heizer, photo by Tom Vinetz

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Megalith slated to become part of Michael Heizer's Levitated Mass, prepared for transport from quarry in Riverside County to the Los Angeles County Museum of Art, 2012
2012 © 2012 Michael Heizer, photo by Tom Vinetz

LACMA

Name:

PROJECT PLANNING
Artwork in Focus:
Essential Question:
Core Content:
Line of Inquiry:
Equal Voicing:
Revision:
Presentation:
Reflection:

Name:

PROJECT CALENDAR

Driving Question:

Monday	Tuesday	Wednesday	Thursday	Friday
WEEK ONE				
Goals:				

Monday	Tuesday	Wednesday	Thursday	Friday
WEEK TWO				
Goals:				

Name:

PROJECT CALENDAR

Driving Question:

Monday	Tuesday	Wednesday	Thursday	Friday
WEEK THREE				
Goals:				

Monday	Tuesday	Wednesday	Thursday	Friday
WEEK FOUR				
Goals:				

Classroom Activity

Building a Metropolis

Essential Questions	What forms serve as the building blocks for a metropolis? How do artists and mathematicians design the built environment?
Grades	3–6
Time	Two to four class periods
Art & Math Concepts	Form, interval, grid, quadrant, space, sculpture
Materials	Colored masking tape, measuring tape, cardboard, a variety of recycled materials (cardboard cylinders, packing material, plastic containers, bottle caps, etc.), glue, scissors, white and colored tempera paint, brushes, water, paper towels. Optional: construction paper, wooden dowels or sticks.

Talking about Art

View and discuss the photographs and engineering map of Chris Burden's *Metropolis II* (2011) included in the printed and digital curriculum. Watch the spotlight video of *Metropolis II* on *Unframed The LACMA Blog* at http://lacma.wordpress.com/2012/01/10/ metropolis-ii.

What are the first words that come to mind when you see *Metropolis II*? What three-dimensional forms, such as cubes, cylinders, or spheres, do you see? How are the forms arranged to create a city? What other urban elements do you notice? What is the relationship between the building forms and the freeway tracks? How are they integrated into the overall design?

How does looking at photographs of *Metropolis II* compare with watching a video of the sculpture? What did you notice about the artwork from the video that you did not notice in the photographs? What do you think it might look, sound, and feel like to experience *Metropolis II* as a miniature resident? How would it compare to living in a life-size city?

An engineer worked alongside the artist to design and build *Metropolis II*. First, the engineer sketched a simple two-dimensional shape to represent the base of the sculpture. Then, he mapped out the track configurations using string and pen. He marked the string tracks with pen at five-foot scale intervals to guide construction. Lastly, artists added wooden and tiled buildings in between the tracks to mimic the look and feel of a real city.

How does *Metropolis II* compare with the look and feel of your neighborhood? How would you describe the natural landscape of the community? How would you describe the man-made or built environment? What three-dimensional forms comprise these types of environments?

Making Art

Create a classroom metropolis by, first, analyzing a map of the school neighborhood. What landmarks surround the school? What buildings, roadways, bridges, and parks do you notice? Visit some of these structures and sketch the forms that they take (rectangular, triangular, spherical, etc). If you could add forms, structures, or other elements to the neighborhood, what would you add and why?

Place four large pieces of cardboard on the classroom floor, creating four equal quadrants. Lay a simple city grid on top of the cardboard using colored masking tape. Use one color to map north-south thoroughfares and another color to map east-west streets. Keep the map simple, leaving negative space or plots of land in between roads. Divide students into four groups, assigning each group a different quadrant to build. They can use the cardboard as a base to adhere recycled sculptural materials. Forms such as rectangular prisms and cylinders should represent the different structures or spaces that they would add to the neighborhood. Encourage them to work with large forms first, then add smaller forms as details later.

When construction is complete, whitewash the entire city with quick-drying white tempera paint. When dry, add windows, doors, and signage using tempera colors. Use colored construction paper, dowels or sticks, and other recycled materials to add trees, plants, and flowers to the natural landscape. Students can also bring toy cars or toy people from home to turn the sculpture into a full-fledged city.

Reflection

Move the entire sculpture into the auditorium and invite the school community, including local politicians, city planners, and neighborhood council members, to a city ribbon-cutting ceremony. Ask students to reflect on how they used the languages of art and math to build their city, and to share their experience with the professionals in attendance.

Curriculum Connection

Analyze the local city council district's land use map with students. What resources (housing, work, recreation, and transportation) are currently available to residents? What needs will arise in the future? How can artists, mathematicians, engineers, and environmental scientists address these needs together?

Classroom Activity

2-D to 3-D Symmetry

Essential Question How do artists use geometry and symmetry to create two- and three-dimensional compositions?

Grades K–3 & Special Day Classes

Time One class period

Art & Math Concepts Line, shape, form, two and three dimensions, positive and negative space, symmetry, balance, composition

Materials Pencil, colored construction paper, scissors, glue, rulers. Optional: cardboard.

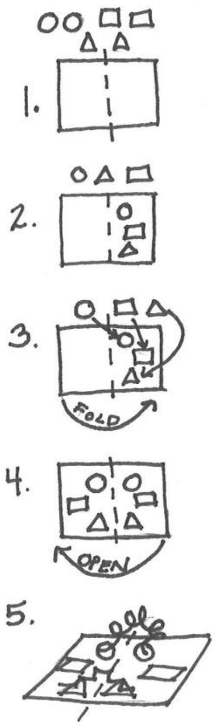
Talking about Art View and discuss the photographs and planning diagrams of Chris Burden's *Urban Light* (2008) included in the printed and digital curriculum. Watch the time lapse video of *Urban Light* from day to night included on the curriculum CD.

What do you notice about *Urban Light*? Describe the lines that you see. Are they straight or curvy? How are the lines arranged? What more can you find, including shapes (two-dimensional) and solids (three-dimensional forms)? The arrangement of lines, shapes, or solids in an artwork is called composition. What are some words to describe this composition? The lines, or lampposts, are arranged to create symmetry. With your hand, draw the composition's line of symmetry in the air. Can you estimate the number of lamps on either side?

Gather students and stand together in a circle. Ask one student to join the center of the circle and lift their arms up like the letter "T," to establish the line of symmetry. Next, ask two volunteers to create lines with their bodies and place themselves on either side of the line of symmetry. Are you a curvy or straight line? Have volunteers join two at a time to add to the composition. Are everyone's lines symmetrical? What do you need to change to create a symmetrical composition?

Burden arranged *Urban Light*'s 202 antique lampposts symmetrically by installing them carefully on a grid. Do you notice any patterns in the arrangement? Lamps of the same design are grouped together and the groups are ordered by height, to create three-dimensional symmetry in the form of a pyramid.

Making Art



Create a symmetrical collage by folding a piece of construction paper vertically or horizontally, to create a line of symmetry. Open the paper and lay it flat on the table.

Cut pairs of geometric shapes out of construction paper. To create two identical shapes, fold a piece of construction paper in half, draw a simple shape such as a triangle or square on one side, then cut along the drawn lines. For younger students, you can also prepare stencils by cutting shapes out of cardboard for students to trace. When you have gathered a variety of shapes, start arranging them on one side of the line of symmetry. When you have reached a desired arrangement, glue them down with a glue stick. Complete the composition by carefully matching shapes and laying them on top of each other. Then, put a small dab of glue on top of each shape and carefully fold the paper again. Open the paper to reveal a perfectly symmetrical composition.

For older students, build on two-dimensional symmetry by adding three-dimensional elements. Measure and cut a variety of strips using a ruler then fold the strips to create texture. Next, arrange the strips so that they connect similar shapes on either side of the line of symmetry, turning the collage into a symmetrical paper sculpture.

Reflection

Turn to a partner and share one thing that you like about your collage. Ask older students to talk about the process of rearranging the composition to reach symmetry. Then, share artworks with the class by answering these questions: What types of lines and shapes did you use? What colors did you use and why? Point out two parts of the composition that exemplify symmetry.

Curriculum Connection

As a team, measure the height of three or more items in the classroom using a ruler. Arrange the items according to length or height. Collect doubles of each item, identify a line of symmetry, and then arrange the items symmetrically as Burden did in *Urban Light*.

Classroom Activity

Levitating a 25-lb Mass

Essential Question	How do artists create art installations using engineering concepts?
Grades	9–12
Time	Two to three class periods
Art & Math Concepts	Estimation, structural engineering, weight-bearing technology, balance, illusion, installation
Materials	Paper, pencil, popsicle sticks, wood glue, objects weighing at least 25 pounds (i.e., rock, cinder block, brick, watermelon). Optional: blueprint paper.

Talking about Art

View and discuss the photographs and preliminary sketch of Michael Heizer's *Levitated Mass* (2012) included in the printed and digital curriculum. Watch documentation of the megalith's planning, transport, and installation from LACMA's Video Library at https://www.lacma.org/video/levitated-mass.

What questions do you have about *Levitated Mass*? If you could, what would you ask the artist and the engineer about the planning, transport, and installation of this work?

Heizer conceived of this monumental sculpture in 1969. At a Riverside, California quarry 40 years later, he identified the perfect rock to serve as the artwork's specimen. First, mathematicians studied the rock, taking detailed measurements. Based on these measurements, engineers designed a massive transporter to carry the rock and construction workers used hydraulic jacks to lift it. To ensure a safe journey to LACMA, city planners devised a travel route, identifying bridges and streets that could accommodate the rock's 340-ton weight. It traveled for 10 days over 100 miles, spanning 4 counties and 22 cities before it arrived at Hancock Park. A custom-built crane lifted the rock into place, on top of a ramp made of concrete and reinforced steel. Lastly, granite landscaping and palm trees were added to reference the rock's desert home. It is Heizer's close attention to the rock and its surrounding environment that transformed this artwork and engineering feat into a sculptural installation.

Making Art

Installations are artworks that take the form of three-dimensional environments. Create your own installation that explores art and engineering concepts of weight and levity by, first, splitting into groups of two to three. Decide who will take the role of artist, mathematician, and engineer and how you will work together to "levitate" a 25-pound mass using just popsicle sticks and glue.

Analyze the challenge at hand by brainstorming engineering designs. Designs that employ triangles and pyramids, shapes and forms with a heavy base and a pinnacle on top, disperse pressure and provide strength and stability. The ultimate goal is to build structural integrity using as few sticks as possible. Have team members work together to create sketches of possible supports with the above limitations. Then, estimate the number of sticks required for execution. Remember, you must use whole sticks as the building units.

Next, transform the sketches into three-dimensional supports. Experiment by testing out your design and making needed adjustments. You can use combinations of triangles and squares to make any geometric solid (e.g., square pyramid, triangular pyramid, trapezoidal prism, etc.). Work together to glue the final configuration.

When finished, engineers should ensure that the adhesives and sticks are structurally sound. Mathematicians should write an equation for calculating the total number of sticks. Artists should document the final arrangement on a sheet of blueprint paper. Allow the structure to dry overnight then work as a team to lift the 25-pound mass into place. Take a look from many angles. Does the rock appear to levitate?

Reflection

Does the final design match the original sketch? If not, what changes did you make along the way? How did you work together to complete the challenge?

Place the results of your experiment outside on the school campus. What can you add to transform the levitating rock into a miniature art installation? Document your installation by photographing it from different angles in the sunlight.

Curriculum Connection

Compare the number of sticks it took to levitate the mass with your original estimate. How accurate was your prediction? If you were to double the weight of the mass, how many more sticks might you need? Try calculating the total number of sticks in different weight and pressure scenarios.

Classroom Activity

Straw Polygon Sculptures

Essential Questions

How do artists find inspiration in nature and math? How do they build patterned forms using three-dimensional units?

Grades

6–9

Time

One to two class periods

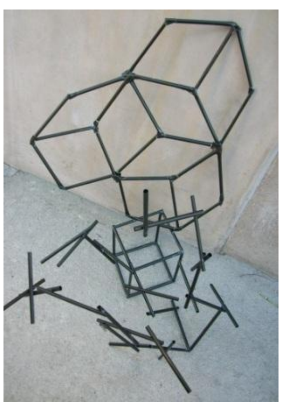
Art & Math Concepts

Line and shape, organic and geometric, polygon, form, polyhedron, volume, space, balance

Materials

Pens, rulers, protractors, compass, plastic drinking straws, paper clips or fasteners, rubber bands, duct tape, cardboard. Optional: air-drying clay, construction paper, colored tape, hot glue

Talking about Art



View and discuss the photographs of Tony Smith's *Smoke* (1967, fabricated 2005) and the artist's diagram included in the printed and digital curriculum. Watch the time lapse video of *Smoke*'s construction from LACMA's Video Library at www.lacma.org /video/ time-lapse-images-smoke.

Take a look at the sculpture from multiple viewpoints. What shapes and forms do you notice? Are they curvy shapes or angular forms? In art, curvy shapes are described as organic because they mimic shapes from life, while angular shapes are called geometric because they exemplify mathematical concepts. Do these mathematical shapes remind you of forms from life?

Smith was known for his minimalist sculptures that employ simple shapes in elaborate construction. The sculpture's outline appears organic, but the individual parts that comprise the structure are geometric.

Two basic polyedra or triangular units—a tetrahedron (a three-dimensional solid made of four triangular faces) and an octahedron (formed by two tetrahedrons opened at a vertex and conjoined)—are scaled to life size, repeated, and combined to make up *Smoke's* frame. The overall hexagonal formation references the shape of a honeycomb, pointing to Smith's fascination with positive and negative space and porous forms from life.

Making Art

Using a pen and a photocopy of *Smoke,* circle the following geometric shapes: square, rectangle, triangle, hexagon (6-sided polygon), octagon (8-sided polygon), and nonagon (9-sided polygon). Are they uniform or irregular shapes?

In small groups, use plastic drinking straws to create a simple polygon. Choose from a variety of materials to connect the straws together, such as rubber bands, clay, paper clips or fasteners, and duct tape. Create a replica of the polygon to serve as the base for a sculpture then produce more polygons to use as building units. Connect the units together or build outward from one unit, both vertically and horizontally, to create a pattern in three dimensions. If necessary, adhere the sculpture with hot glue for structural reinforcement and attach to a cardboard base.

Now that students have created a strict patterned sculpture, ask older students to experiment with form and balance by creating a free-form organic sculpture. Divide students into groups of three and ask each to use straws and adhesives to create a free-form unit. When finished, experiment with attaching the three units together, ensuring balance and structural integrity, to create a collaborative work of art.

Reflection

Display patterned and free-form sculptures together in the class-room and facilitate a gallery walk. View sculptures from above and below, and from many different perspectives. Are the individual units that comprise the patterned sculptures regular? When you walk around a free-form sculpture, how does the outline change and transform? Compare and contrast the different works. Which do you prefer and why?

Ask each group to take their collaborative sculpture and install it in a location on the school campus. Lead a walking tour of all of the sculptures and note, in a sketchbook, the different shapes that you see, such as triangles, hexagons, octagons, and nonagons. Draw a sketch of each sculpture within its natural environment. Are any shapes or forms reflected in the landscape around it?

Curriculum Connection

Revisit the patterned sculpture and measure one of its individual units. Using these measurements, calculate the total volume of the sculpture. Then, work together as a team to calculate the volume of the free-form sculpture.

Building STEAM: Art, Math, and Technology

Selected Resources

Online Resources

A Report on the Art and Technology Program
Los Angeles County Museum of Art
www.lacma.org/art/reading-room
Read about the history of LACMA's commitment to technology through the Art + Technology Program of 1967–71, which paired contemporary artists with the industrial and scientific communities of Los Angeles. Access the report on the Pacific Standard Time tab.

STEAM Education Resource Center
PBS Teachers
www.pbs.org/teachers/stem
Explore STEM lesson plans such as "Heavy Lifting," a challenge to design and build a crane out of recycled materials by experimenting with the properties of weight and force.

MIT+K12
Massachusetts Institute of Technology
http://k12videos.mit.edu
Use MIT's collection of K–12 student-focused videos as classroom teaching tools. Search by grade level or subject area, or create and upload your own video assignments.

MIT App Inventor
Massachusetts Institute of Technology
http://appinventor.mit.edu/teach
Take STEAM Education into the digital age by teaching students how to design an app. Use the curriculum and media library to find lesson plans and visual aids.

Related Curriculum Materials

Evenings for Educators resources include an illustrated essay, color images, classroom activities, and related resources. Printed curriculum is available through LACMA's Education Department or browse selected curricula online at www.lacma.org (Programs/Education/Evenings for Educators).

Preserving the Past: Conservation at LACMA
December 1995

Art, Ecology, and the Environment
May 1997

The Visible World: Observation in Art and Science
April 1999

Wonderment and Interaction: Science, Technology and Art
February 2004

The Urban Environment in Art
March 2006

Books for Teachers

Hallermann, Sara, John Larner, and John R. Mergendoller. *Project-Based Learning in the Elementary Grades.* Novato: Buck Institute of Education, 2011.
A practical guide to Project-Based Learning (PBL), designed for K–5 teachers. Contains project planning, assessment, and management tools as well as sample projects from different grade levels and subject areas.

Larner, John. *Project-Based Learning Starter Kit.* Novato: Buck Institute of Education, 2009.
Tools and tips for PBL in the middle- and high-school years. Includes project-ready rubrics and links to online resources.

Riley, Susan M. *STEAM Point: A Guide to Integrating Science, Technology, Engineering, the Arts, and Mathematics through the Common Core.* Seattle: CreateSpace Independent Publishing, 2012.
A guide for teachers and administrators on *STEAM* and Common Core State Standards integration.

Sousa, David A. *From STEM to STEAM: Using Brain-Compatible Strategies to Integrate the Arts*. Thousand Oaks: Corwin, 2013.
Techniques, lesson plans, and templates to help educators integrate artmaking into daily instruction, building skills critical to STEM Education.

Books for Students

Moscovich, Ivan. *The Big Book of Brain Games: 1,000 PlayThinks of Art, Mathematics, and Science*. New York: Workman Publishing Company, 2006.
A collection of brainteasers that test visual and problem-solving skills using numbers, patterns, geometry, logic, and probability.

Ruffler, Walter. *Paper Models that Move: 14 Ingenious Automata and More*. Mineola: Dover Publications, 2011.
A world of paper engineering through projects that explore levers, gears, cranks, and other devices.

Salvadori, Mario. *The Art of Construction: Projects and Principles for Beginning Engineers and Architects.* Chicago: Chicago Review Press, 2000.
The basic principles of construction for all types of urban structures, including bridges, skyscrapers, and other architectural works. Projects employ accessible everyday materials.

Tang, Greg. *The Art of Problem-Solving.* New York: Scholastic Press, 2003. An exploration of four basic rules in problem-solving through works of art: keeping an open mind, looking for unusual number combinations, using multiple skills, and looking for patterns.

Woods, Michael. Ancient Machine Technology: *From Wheels to Forges*. Minneapolis: Twenty-First Century Books, 2011.
A history of the evolution of technology through the work of ancient artisans to contemporary engineers.