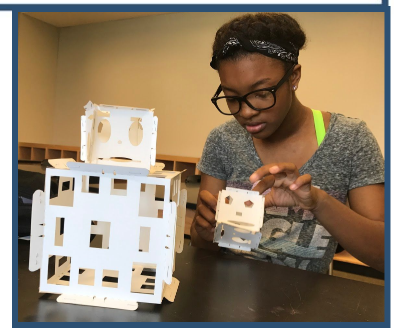
SCOPES-DF

Fab Tested

**GeoConstructix**
*(Kevin Hardin, Teachingineering / MC2 STEM High School, Cleveland Ohio)*



| | |
|---|---|
| Student Mastery Level | X Novice |
| Educator Experience | X Intermediate |

| Targeted Age/Grade | Original Context | Subjects | Instructional Time | Digital Fabrication Tools |
|---|---|---|---|---|
| • 9-12 / 4-6<br>• 13-14 / 7-8 (middle school) | • In classroom<br>• Special project in Fab Lab or Makerspace | Engineering<br>Math | 60 minutes | Laser cutter |

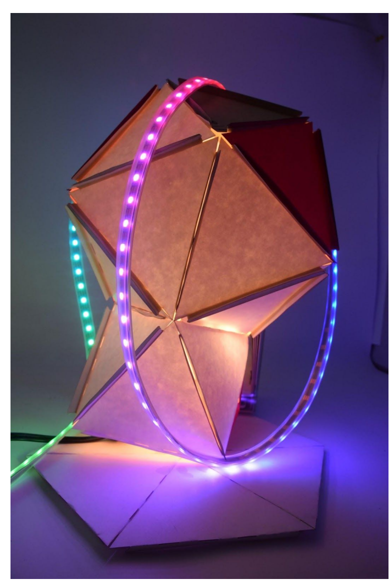
**Snapshot:**
Students will work with a series of successive methods-based exercises to learn the fundamentals of geometry and fabrication techniques with increasing levels of complexity.

**Tags:** Sculpture, Build Challenge, Geometry

**Collections**: Fab Tested

# Summary

The primary focus of this lesson is on the inter-relationship between geometry and fabrication. GeoConstructix adapts digital fabrication concepts by focusing on the inter-relationship between geometry and Computer-aided design and manufacturing (CAD/CAM) techniques. The lesson's scaffolding structure allows students to work with a series of successive methods-based exercises that rely on both digital modeling and prototypes. Students "learn by doing." By the end of this lesson, students will learn the fundamentals of geometry and fabrication techniques with increasing levels of complexity. This is an introductory lesson in digital fabrication.



# Lesson Objectives

Student solution demonstrates:

- clear and accurate understanding of finding an angle measures, perimeter, and area of triangles and quadrilaterals.
- accurately and efficiently finding the surface and area and volume of prisms
- the ability of interpreting a problem accurately in order to find angle measures, perimeter, or area.
- an appropriate and efficient strategy that results in a correct answer
- clear and accurate understanding of the characteristics of triangles and quadrilaterals.
- clear and accurate understanding of how a net represents a three-dimensional figure
- precise use of appropriate terms to explain reasoning in geometry concepts.
- precise use of appropriate terms to explain the surface area and volume of solids

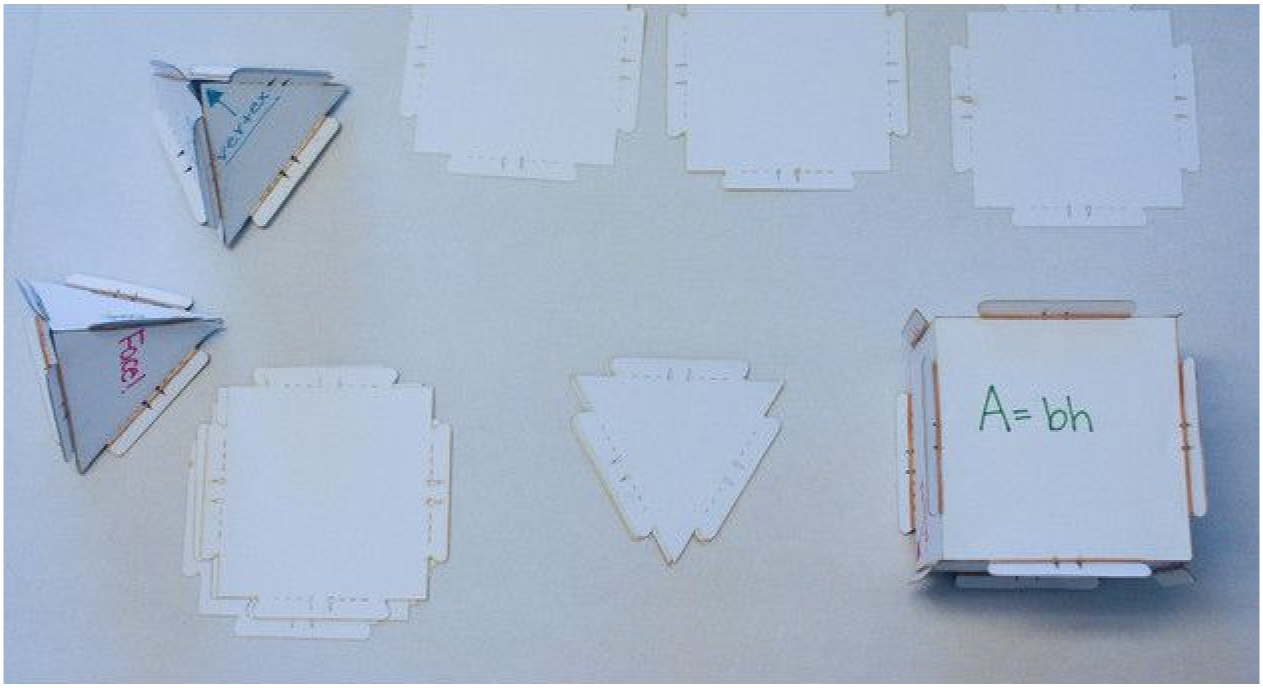
# Details

**Key Vocabulary / Terms**

Geometry
Area
Volume
Symmetry
Angles
Fundamental shapes
Face
Edge
Vertex
Cube
Tetrahedron
GeoConstructix

**Key Formulas**

Area of Triangle = ½ base * height
Area of a Square = base * height
Cube Volume = base * height * depth
Tetrahedron = $a^3 / (6\sqrt{2})$ ; a = length of edge




**Materials List**

110 lb Cardstock
Laser cutter
CorelDraw (or similar 2D vector graphics software)
Rubber bands

**Design Files Developed**:

Files downloaded on SCOPES-DF Google Drive

**Readings / Handouts**

GeoConstructix - Grade 7 - Voluminous Sculptures - Student

## Steps

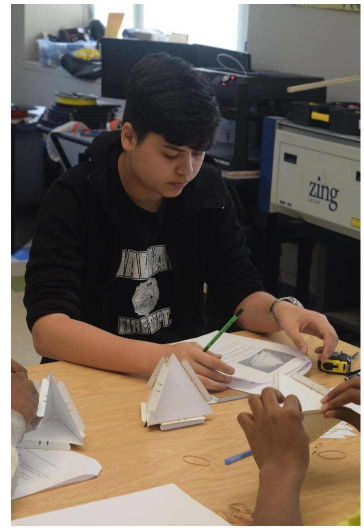
***Map of Lesson***

1. Step 1 - Use GeoConstructix for identifying geometry concepts to create non-digital prototypes
2. Step 2 - Build Your Own Sculpture

**Before the lesson**:
- Teacher will precut the GeoConstructix components. Each piece requires approximately 1.5 minutes.
- If desired, the lesson can be adapted to allow for the students to cut their own components out.

# Step One

**Step One: Identify geometry concepts to create non-digital prototypes (25 Minutes)**




**Guided Instruction:** Students will gain an understanding of the relationship between fabrication process and assembly without technical aspects of digital modeling. Teacher will guide students through an activity in which they use laser cut 2D shapes to construct various 3D objects and learn about geometric shapes.

**Essential Question:** Why is it important to understand the characteristics and distinctions of two-and-three-dimensional figures?

Make sure students have the following supplies before beginning lesson plan:

- 6x square GeoConstructix
- 4x triangle GeoConstructix
- 16x rubber bands

1. **Bell Ringer (15 Minutes)**: Provide students with a working understanding of Area vs. Volume

   On classroom smartboard, have students watch the following Khan Academy tutorials:

   **Intro to area and unit square:**
   https://www.khanacademy.org/math/basic-geo/basic-geo-area-and-perimeter/basic-geo-unit-squares-area/v/introduction-to-area-and-unit-squares

   **Measuring volume as area times length**:
   https://www.khanacademy.org/math/basic-geo/basic-geo-volume-sa/volume-rect-prism/v/measuring-volume-as-area-times-length

   Remind students of definitions:

   **Definition:** Area is the size of a surface of a 2-dimensional object such as a triangle or square. It has units of square inches ($in^2$)

   **Definition:** Volume is the amount of space inside a solid 3-dimensional object such as a cube or sphere. Volume has dimensions of cubic inches ($in^3$)

**2. Transition (1 minute)**: Instruct students that they are to keep a definition list in their notebook; and each time they encounter new geometry vocabulary, add the term to their list.

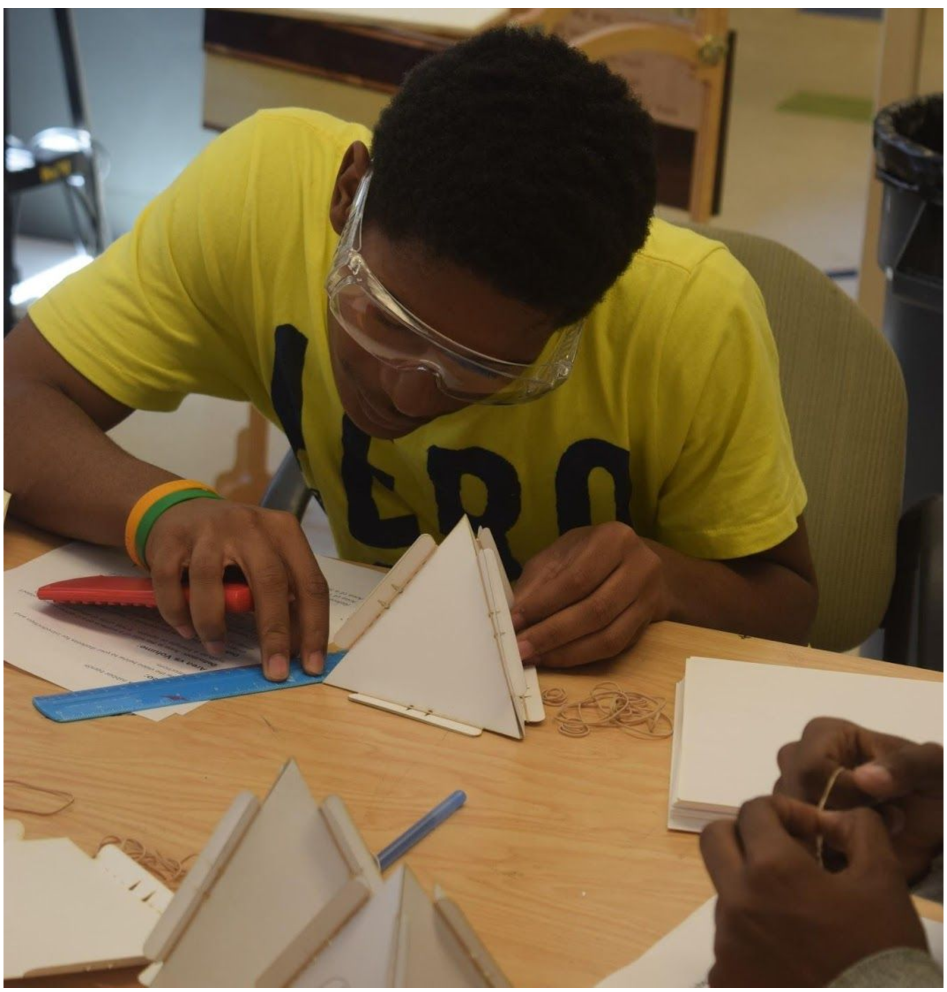
Illustrate each definition with a simple sketch.

Tell students that the following fabrication geometry prototypes will be explored through this initial exercise.

- Building a Cube
- Building a Tetrahedron

**Tell students that two important reference equations are:**

Area of Triangle = ½ base * height
Area of a Square = base * height



**3. Building a cube (3 minutes):**

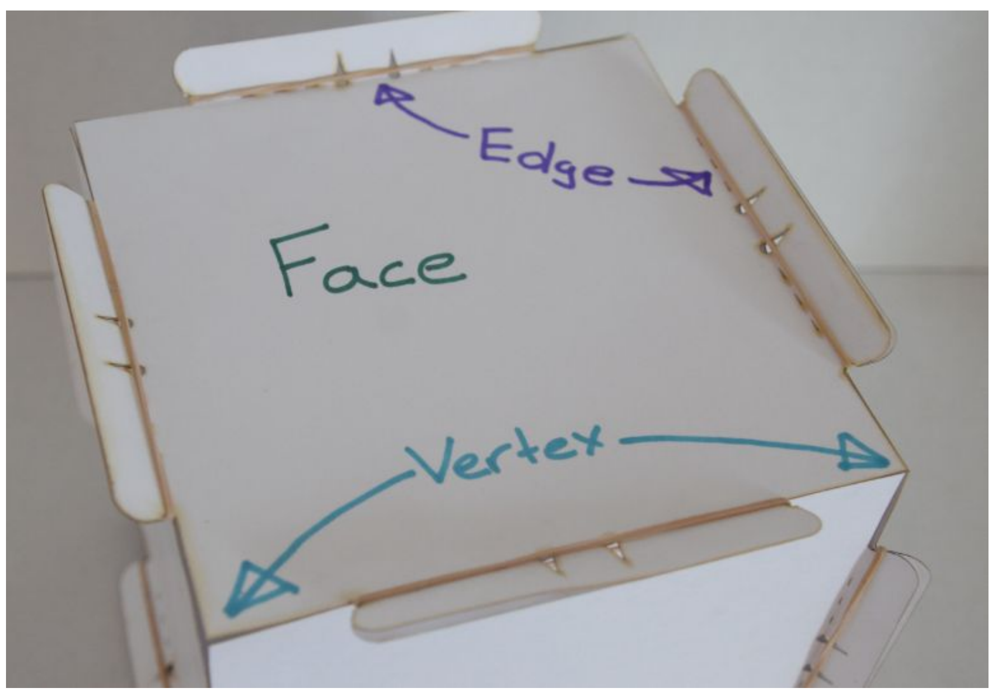
1) Use 6 *square* GeoConstructix to build a cube using rubber bands as shown below.

a) Fold all the flaps along the dashed line

b) Connect edges with rubber bands


2) How many of the following are in your cube?

**Faces:**
**Vertices:**
**Edges:**




3) How many edges come together at each vertex?

4) Measure the length of the edges to calculate the volume?

Cube Volume = base * height * depth

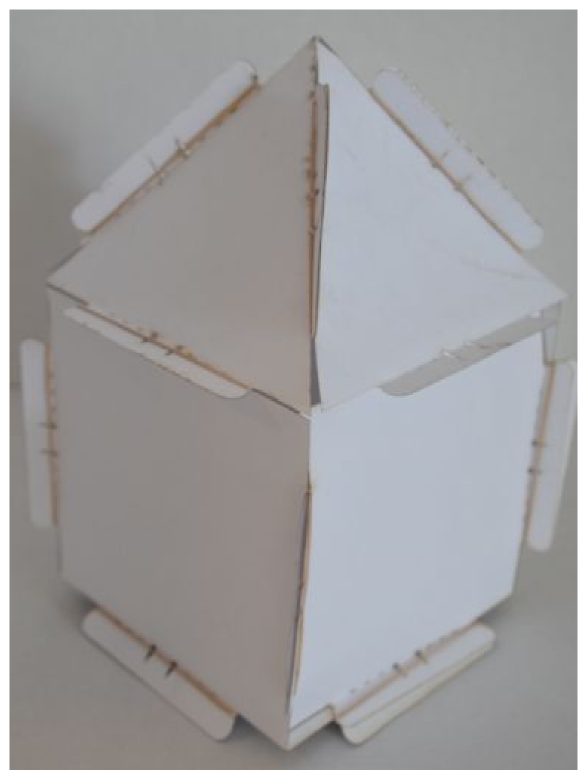
$V_{Cube} = b * h * d$

**4. Building a Tetrahedron (3 minutes)**


A tetrahedron is a 4 sided platonic solid, made of triangles.

- Use 4 GeoConstructix triangles to build the shape
- How many edges come together at each vertex?
- Surface area is the total area of a 3-dimensional object. Find the area of each face and add it together to find the surface area.
- What is the surface area of the tetrahedron?
- What is the volume of the tetrahedron?
  - $V_{tetrahedron} = a^3/(6\sqrt{2})$ ; a = length of edge

**5. Connecting Shapes (3 minutes)**



Connect the cube and the tetrahedron to make the following structure.

What is the total number of:

Edges:
Vertices:
Faces:

What is the total surface area of the new sculpture?

**6. Exit Ticket (10 Minutes)**

1) Describe the difference between area and volume?
2) What is the area of the triangle GeoConstructix?
3) What is the area of the square GeoConstructix?
4) What is the unit of area?

# Step Two

**Step 2: Build Your Own Sculpture**

**Essential Question: In what ways are geometric figures used in real life?**

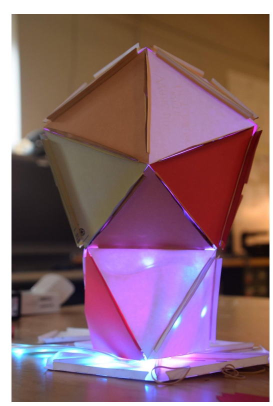
**Warm-up** (10 Minutes): Describe the the fundamentals of laser cutting:

- What  computer program is used to control the laser?
- What does it mean to vector?
- What settings must you change if you want to vector a line?
- What does it mean to raster?
- Describe the required steps to focus the laser?

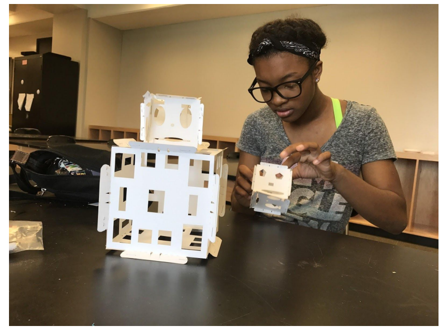
**Question for students:**
- Has anyone seen a laser cutter before?
- Has anyone used a laser cutter before?
- What are some things you might cut with a laser?
- Who knows the steps in the engineering design process?:

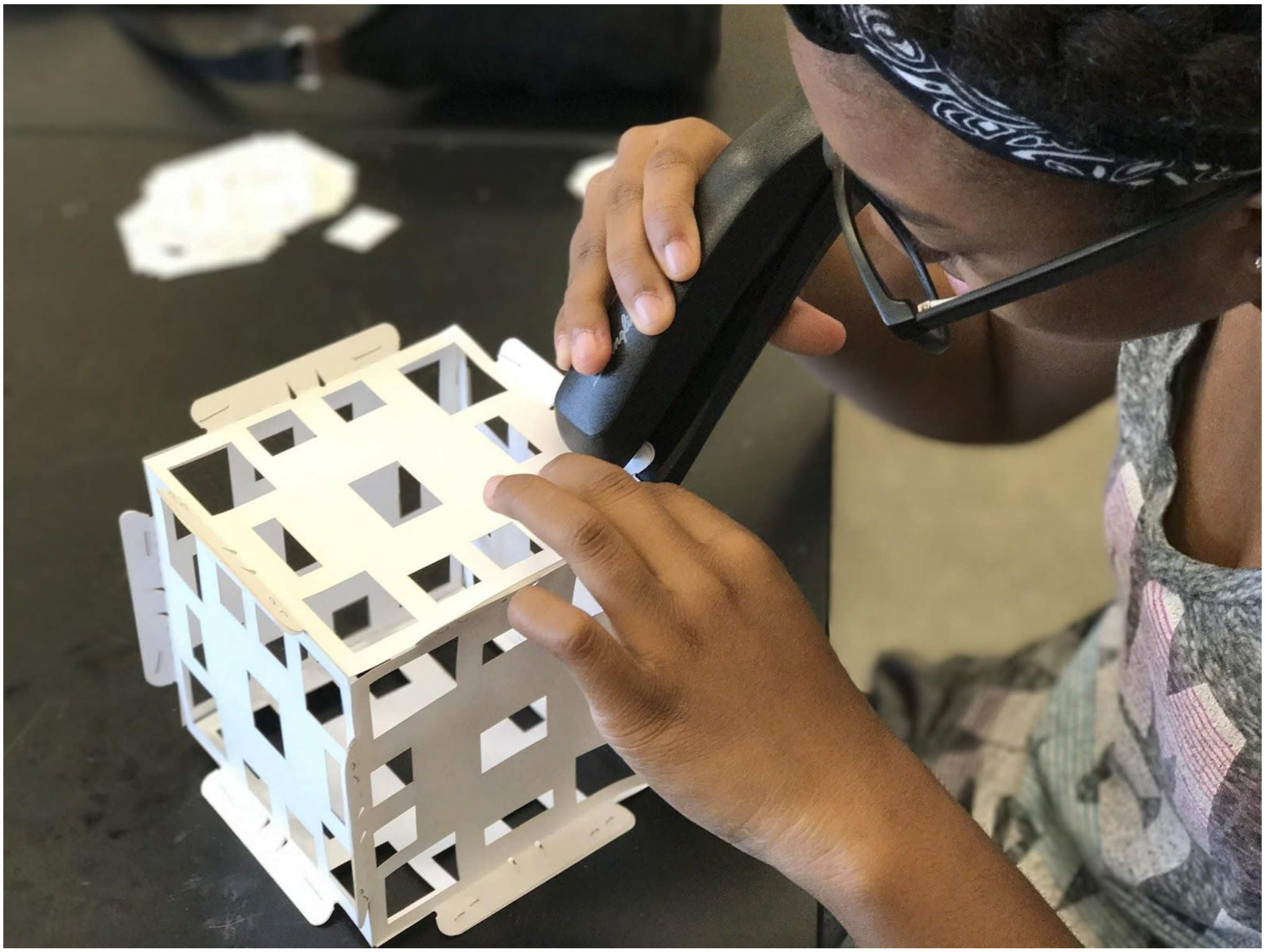
**Making of Shapes**: (50 Minutes)

1. Begin by explaining and modeling: In whole class setting review how to use the laser cutting machine.
    - NOTE: Here's an instructional video from MC2 STEM High School on their Epilog Laser machine: https://www.youtube.com/watch?v=k1OX844Jupo



2. Guide the students to design their own sculptures, using the basic shapes from Step 1 as foundations or jumping off points, and adding other embellishments such etched designs, LED electronics, and other craft materials.
    - Say:
        - To complete your own creative sculpture get additional pieces from the supply bins. Be sure to save supplies for other groups.
        - Use the additional pieces to build your own unique geometric sculpture. Work with your team to connect all of your pieces in an interesting pattern.
    - Show examples for inspiration.





(From Fab Testing in Cleveland (Andrea Fields))

# Outcomes

## Assessments

### Embedded Assessment

Students gain a working understanding of how the laser cutter is used to cut stock into shapes by reviewing and answering the following questions correctly:

- Where can you find the advanced laser cutter controls?
- How do you determine piece size?
- Will the laser cutter use different settings for different materials (yes or no)?
- Where can you find the different settings for each material?
- What is the danger of using incorrect settings?
- What system must be turned on before starting the laser cutter?
- If you are vectoring, what additional piece of equipment must you turn on?

Students will demonstrate their understanding of what a laser cutter can do by creating prototypes of:

- Squares
- Pentagons
- Hexagons
- Triangles

### Summative (End of Lesson) Assessment

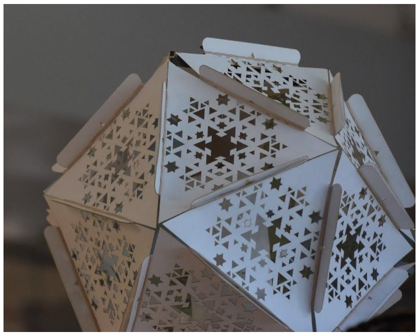
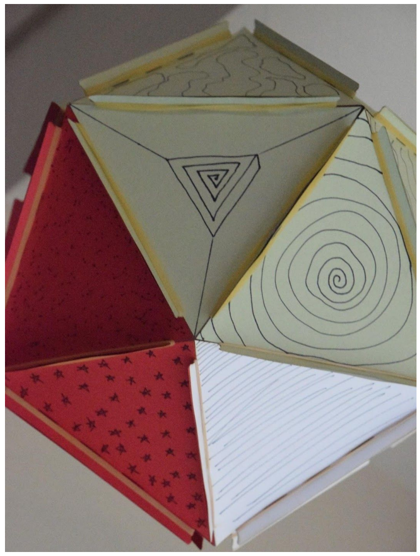
Students will demonstrate their creativity and understanding of geometry concepts and their presentation skills by sharing their sculptures, and reflecting on:

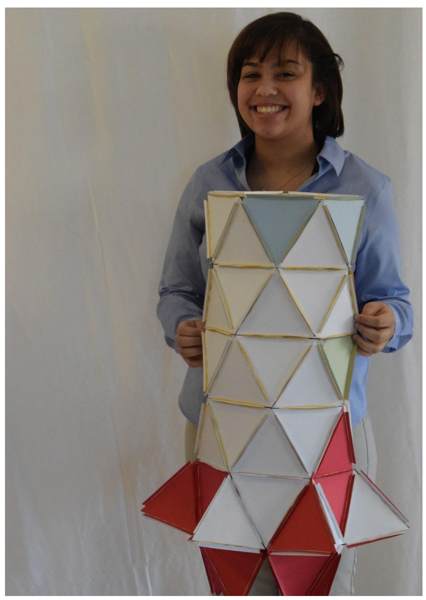
- The total number of:
  - Edges:
  - Vertices:
  - Faces:
- The surface area of their sculpture

Students can take also a picture of sculpture and share on social media using the following hashtag so others can learn from your project: #Geoconstructix

### Finished Student Project Examples

From MC2 STEM HS: https://www.flickr.com/photos/teachingineering/albums/72157684225868135




**More from other Fab Testing in Cleveland:**
https://drive.google.com/drive/folders/0B1pKagGIBY3maHR6OUNCODRvWGc?usp=sharing

**References**

https://www.thingiverse.com/thing:2338278

## Standards

**Common Core Mathematical Practices**

MP.1- Make sense of problems and persevere in solving them.
MP.2 -Reason abstractly and quantitatively.
MP.3- Construct viable arguments and critique the reasoning of others.
MP.4- Model with mathematics.

MP.5-Use appropriate tools strategically.
MP.6- Attend to precision.
MP.7- Look for and make use of structure.
MP.8- Look for and express regularity in repeated reasoning.

**Common Core Mathematics Standards**

5.G.A.1. Use a pair of perpendicular number lines, called axes, to define a coordinate system, with the intersection of the lines (the origin) arranged to coincide with the 0 on each line and a given point in the plane located by using an ordered pair of numbers, called its coordinates.

5.NBT.5: Fluently multiply multi-digit whole numbers using standard algorithm.

6.RP.1: Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.

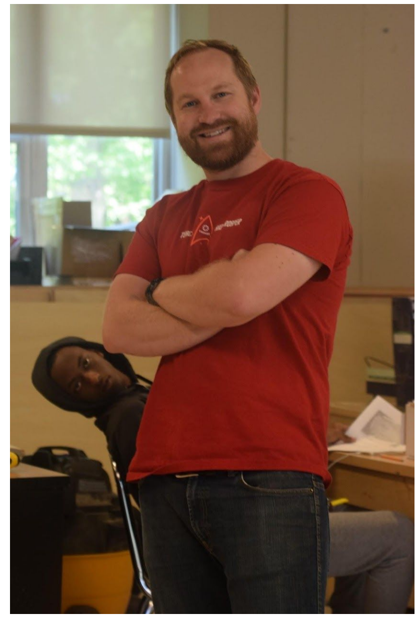
6.RP.3-b: Solve unit rate problems including those involving pricing and constant speed.

6.RP3-d: Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing.

**Digital Fabrication Competencies: I Can Statements**

- (S.1) Safety: I can safely conduct myself in a Fab Lab, observe operations and follow general safety protocols under guidance from an instructor.
- (DP.3) Design Process: I can create analog models (e.g. sketches, small physical models, etc.) to facilitate a design process.
- (DP.4) Design Process: I can record and share my ideas during a design process to document the learning process (e.g. journal writing, group reviews, etc.).
- (DP.5) Design Process: I can work with a group to follow multiple common design process steps (e.g. defining the user, brainstorming, prototyping, iterating, etc.).
- (F.1) Fabrication: I can assemble an object using prefabricated components.
- (SC.1) Sustainability and Commerce: I use scrap and renewable resources like cardboard first, before using higher cost materials. I understand the cost of various raw materials in the Fab Lab.
- (CT.1) Critical Thinking: I can use information in a Fab Lab (or through use of digital fabrication tools and processes) to answer questions about the design process.
- (Q.2) Questioning: I can formulate questions that reveal important aspects of design process including problems and challenges.
- (PS.3) Proposed Solution: I can propose alternative solutions to a design problem through iterations and determine their utility through execution.

# Contributor Profile



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**Organization**: Teachingineering / MC2 STEM High School
**Location** (City, State, Country): Cleveland, Ohio
**Additional Contributors**:

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**Bio**

Kevin is a STEM engineering teacher at MC2 STEM, a public STEM school in Cleveland Ohio. He designs custom curriculum for my students to teach design and manufacturing. You can see over 4000 photographs from inside his classroom on his photography blog. The STEM Engineering website contains project details, student successes, and STEM resources: www.Teachingineering.com

**About MC2 STEM High School Fab Lab**

MC2 STEM High School's Mission is to model a rigorous STEM education in a non-traditional environment through trans-disciplinary curricula, hands-on projects, and community partnerships in Cleveland, OH. Our mission is to engage and enrich all students' by developing critical thinking and problem solving skills, and empowering them to achieve their personal, academic, and community goals. Launching the first public school fab lab in the United States, MC2STEM High School now hosts 4 fab labs, one on each of its three campuses and a Mobile Fab Lab.

http://www.mc2stemhighschool.org/
http://www.clevelandmetroschools.org/domain/1373

## About SCOPES-DF


Fab Foundation's new SCOPES-DF (Scaling a Community of Practice for Education in STEM through Digital Fabrication) project aims to catalyze STEM learning in formal educational environments through digital fabrication technologies and practices found in a Fab Lab or makerspace. Our goal is to build a community of in and out of school K-12 practitioners by co-curating and openly sharing digital fabrication lessons that are aligned to standards, and engaging for students and teachers. This lesson was based on one of over 50 submissions in the first round in June 2017 to be aligned to educational standards, reviewed by educators, tested with youth and educators in Fab Labs, and standardized into a common "Fab Tested" collection to seed the future online community of practice at SCOPESDF.org.

The Fab Foundation is a U S based non profit formed to facilitate and support the growth of the international fab lab network. The Fab Foundation has three programmatic foci: education, capacity building and services, and business opportunity. For more information about the Fab Foundation visit **www.fabfoundation.org**

**Join Us!**

To sign-up for early access or submit an activity, project or lesson in the interim, visit **http://scopesdf.org/get_ involved**.

Email **scopesdf@fabfoundation.org** to volunteer to test these lessons with your students.

FABFOUNDATION Chevron GE Foundation

SCOPES-DF is a collaborative project with funding support from Chevron and the GE Foundation.