

Jason Hoch – Integrated Art STEM Lesson Plan Final Forces on a Kite Grades 9/10 Time 4-6 Periods

NCASS Standards

VA:Cr1.1.1a Use multiple approaches to begin creative endeavors.

VA:Cr3.1.1a Apply relevant criteria from traditional and contemporary cultural contexts to examine, reflect on, and plan revisions for works of art and design in progress.

Visual Arts Standards for Presenting

VA:Pr4.1.1a Analyze, select, and curate artifacts and/or artworks for presentation and preservation.

Visual Arts Standards for Connecting

VA:Cn10.1.1a Document the process of developing ideas from early stages to fully elaborated ideas.

Creating Conceiving and Developing

1. Generate and conceptualize artistic work and ideas.
2. Organize and develop artistic ideas and work. Performing/Presenting/Producing
4. Select, analyze and interpret artistic work for presentation.
6. Convey meaning through the presentation of artistic work. Responding: understanding and evaluating how the arts convey meaning.
7. Interpret intent and meaning in artistic work.
11. Relate artistic ideas and works with societal, cultural and historical context to deepen understanding.

NGSS Standards

HS-PS2-1. Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

MS-PS2-1. Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects.*[Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]

Disciplinary Core Ideas

HS. Energy
HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]

HS. Engineering Design ETS1.C: Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

CCSS for Mathematics

High School Geometry G.SRT.B.4 Prove theorems about triangles. Theorems include: a line parallel to one side of a triangle divides the other two proportionally, and conversely; the Pythagorean Theorem proved using triangle similarity.

G.SRT.B.5 Use congruence and similarity criteria for triangles to solve problems and to prove relationships in geometric figures.

G.SRT.C.6 Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

HSG.SRT.D.9 Derive the formula $A = 1/2 ab \sin(C)$ for the area of a triangle by drawing an auxiliary line from a vertex perpendicular to the opposite side.

HSG.SRT.D.11 Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (e.g., surveying problems, resultant forces).

HSG.GMD.A.3 Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.

Art Integration

As each student builds their own kite, they create a digital story about the process. I would apply digital storytelling to the “Forces on a Kite Lab.” This STEM-based topic can be enhanced if students manufacture an artifact that depicts the process by which they made their kites. As part of the project a student must incorporate elements of digital storytelling. Kite-building in our class is often full of modifications and design updates. I also require students to create a product using an unspecified process. The process documented by the digital stories allows other teachers and students to replicate the lesson.

Each student constructs a tetrahedron and describes the linear, area, and volume measurements using non-traditional units of measure. Four tetrahedra are combined to form a similar tetrahedron whose linear dimensions are twice the original tetrahedron. The area and volume relationships between the first and second tetrahedra are explored, and generalizations for the relationships are developed.

Justification

The digital stories will provide examples of the design decisions previous students made given similar constraints. These examples serve as benchmarks of what was attained in the years prior; therefore, we would have a mark by which to measure the current class’s performance. Ideally, I would hope we could continue to improve the aspects of the construction each year.

Digital storytelling through our kite project would create interwoven disciplinary content via the integration of history, science, math, arts, world language, and English. To integrate history and English students would use authentic documents from the Library of Congress. One such example is the 1903 National Geographic Magazine piece about the tetrahedron structure used in kite-building. The article was written by Alexander Bell, and includes more than 60 pictures and diagrams of the tetrahedron shape. The students could analyze the pictures to look for patterns within the design. This would lead to discussions of the fundamental mathematical topic of how symmetry and equilibrium affect the flight of the kite structure. Students could create an interactive or animation in which the kite structure could be manipulated to predict variations in kite design and how it changes flight. To incorporate world language, students would include a discussion of the comparisons of different cultural uses of kites over time. They could write or translate key words relating to kite design in that language.

Content Background

Newton's third law of action and reaction states that for every action there is an equal and opposite reaction.

Bernoulli's theorem states that as air passes below a wing, air also passes above it. The air on the top of the wing moves a longer distance over the curved surface of the wing, thus it moves faster, reducing the pressure above the wing. The air below the wing moves more slowly, causing the air pressure below the wing to be larger than the pressure above the wing. It is the change in relative pressures above and below the kite that allows the kite to lift.



Figure 1. Example of tetrahedral kite.

Figure 4. Four-cell tetrahedron



Figure 5. Bridle attachment



Kites were the first flying devices ever made by humans. The word “kite” comes from a bird in the hawk family known for its grace in the air. Kites come in a wide variety of shapes and sizes and have been used for many purposes throughout history, although today, kite flying is done largely for recreation. See Figures for examples of a tetrahedral kites, the type that students will be manufacturing in the activity.

5E Lesson Plan	
<p>Engage The purpose for the ENGAGE stage is to pique student interest and get them personally involved in the lesson, while pre-assessing prior understanding.</p>	<p>Objectives <i>Webb’s Depth of Knowledge (1-4)</i> :</p> <p>Students will create a digital story including components of the kite construction process. The story will include activities in the lesson progression.</p> <p>Students will create digital stories that include a summary all aspects of the "Forces on a Kite" lesson. The story must contain computer-based images, text, recorded audio narration, video clips, and music. Stories may vary in length, but must last between two and ten minutes.</p> <p>Students will construct a tetrahedron in two different colors.</p> <p>Students will arrange the two pieces of paper to build a three-dimensional object that will have four congruent equilateral triangular faces.</p> <p>Student will use context clues summarizing usages of kites over time.</p> <p>Students will identify and explain phenomena in terms of concepts as they relate to what helps a kite fly, other than the wind.</p> <p>Students will determine which geometric solid has the smallest number of sides.</p> <p>Students will investigate how triangles – single and multiple units – are used in the construction of various structures such as bridges and towers.</p> <p>Students will predict and draw examples of how making an airplane larger allows it to carry larger and heavier objects.</p> <p>Begin with the Tetrahedron Puzzle.</p> <p>Give each group two copies of the Tetrahedron Puzzle in two different colors of paper.</p> <p>Instruct the students to cut around the perimeter of the template. Fold the piece on each of the segments. Match each of the tabs with their corresponding letter. Use scotch tape to tape the tabs on the outside of the corresponding sides.</p> <p>Instruct each group to use two pieces, one of each color, to put the two three-dimensional pieces together in some way so that the completed three-dimensional object will have four congruent equilateral triangular faces. The finished object is a tetrahedron.</p> <p>Allow students time to explore possible ways to put the two pieces together. Many will eventually discover that the square faces can't be part of an equilateral triangle and can be hidden by putting the two square faces together.</p> <p>If this doesn't form the tetrahedron, then ask if the two square faces can be put together in another way. By rotating one of the pieces 90°, the tetrahedron will be formed.</p>

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	<p>Set the model aside as it will be referred to later.</p> <p>Next, lead a discussion about past experiences with kites. Ask students the questions one at a time. Invite them to write down the answer as soon as they know it and tell which fact helped them figure it out. Collect their responses and then create a chart showing the results.</p> <p>Ask: What popular children’s toy:</p> <ul style="list-style-type: none">• is used by teams of adults in competitions around the world?• is often featured in poetry, legends, and folk tales?• originated in China at least 3,000 years ago?• was outlawed during the 18th century because it distracted shopkeepers from their duties?• has been used to pull boats, carriages, sleds, and ice skaters?• is a traditional New Year’s gift for Japanese children?• has led directly to major scientific discoveries?• helped make Benjamin Franklin, Alexander Graham Bell, Wilbur and Orville Wright, Leonardo da Vinci, Guglielmo Marconi, and Homan Walsh famous? <p>Answer: The kite.</p> <p>Besides wind, what helps to make a kite fly? Lead students to ideas such as materials, aerodynamics, durability, etc. List their ideas on the board and discuss the pros and cons of each.</p> <p><u>Tetrahedron Puzzle</u> http://illuminations.nctm.org/uploadedFiles/Content/Lessons/Resources/9-12/TetraPuzzle.pdf NSTA Tetrahedron Kites http://www.nsta.org/publications/news/story.aspx?id=49092 <u>Soar with Kites</u> http://www.educationworld.com/a_lesson/lesson/lesson056.shtml#sthash.zSM5panp.dpuf</p>

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<p>Explore The purpose for the EXPLORE stage is to get students involved in the topic; providing them with a chance to build their own understanding.</p>	<p>Objectives <i>Webb’s Depth of Knowledge (1-4)</i> :</p> <p>Students will arrange the straws to make two congruent equilateral triangles. Students will construct a 4-sided equilateral triangle so that each side is the length of one straw. Synthesize concepts in the tetrahedron puzzle <i>engage</i> section. Each student will design a three-dimensional tetrahedron using the materials provided.</p> <p>Each group leader should distribute six straws. Instruct the students to use three straws to make an equilateral triangle, so that the length of each side of the triangle is one straw. Students will have no trouble with this. Then, tell them to use two more straws to make two congruent equilateral triangles with the five straws so that the length of each side of the triangles is one straw. Again, students will have no trouble with this. Ask them to describe the shape they have made. Responses will likely include: two equilateral triangles, a parallelogram, and a rhombus. Use the last straw with the other five to make four congruent equilateral triangles so that the side length of each triangle is one straw. This is more difficult because the students try to do it in a plane. Eventually, however, a student will realize that the object can be three-dimensional and will construct a tetrahedron. To help the process along, refer the students to the tetrahedral puzzle they have in front of them.</p> <p>The three-dimensional tetrahedron frames soon will be covered with tissue paper; they will be referred to as cells. Four cells combine to form the basis of the kite.</p>
<p>Explain The purpose for the EXPLAIN stage is to provide students with an opportunity to communicate what they have learned so</p>	<p>Objectives <i>Webb’s Depth of Knowledge (1-4)</i>:</p> <p>List the basic elements of flight as it relates to a kite. Summarize the construction of a 3-dimensional tetrahedron using digital storytelling elements. Apply concepts of digital storytelling to connect the kite design to basic elements of flight. Develop a logical argument to assess important forces in basic kite manufacturing. Cite evidence differentiating using diagrams with written captions that include the kite system, processes, and vocabulary. Ask them to describe the shape they have made. <i>Vocabulary/Definitions</i>:</p>

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<p>far and figure out what it means.</p>	<p><i>drag:</i> A frictional force acting on a body (as an airplane) moving through a fluid (as air) parallel and opposite to the direction of motion.</p> <p><i>lift:</i> The component of the total aerodynamic force acting on an airplane or airfoil that is perpendicular to the relative wind and that for an airplane constitutes the upward force that opposes the pull of gravity.</p> <p><i>gravity:</i> A force of attraction between two objects due to the mass of the objects and the distance separating them.</p> <p><i>tension:</i> Two pulling forces directly opposing each other that stretch an object. Tension in the string keeps a kite from flying away.</p> <p><i>relative wind:</i> The airflow produced by the aircraft moving through the air. The relative wind is in a direction parallel with and opposite to the direction of flight.</p> <p><i>industrial engineering:</i> A branch of engineering dealing with the optimization of complex processes or systems. It is concerned with the development, improvement, implementation and evaluation of integrated system. The term originally applied to manufacturing, but has grown to encompass any methodical or quantitative approach to being efficient in how a process, system or organization operates</p>
<p>Elaborate/Extend The purpose for the EXTEND stage is to allow students to use their new knowledge and continue to</p>	<p>Objectives: Students will make observations about the volume of a tetrahedron as it compares to the volume of an octahedron. Students will create a kite that combines the cells each individual class member created. Students will create a hypothesis related to lifting force for a variety of kites. Students will develop a “fair test” to test the hypothesis they develop regarding the lifting power of different variety of kites.</p>

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explore its implications.	<p>Students will evaluate their hypothesis, based on the data the class collects. After students complete this opening puzzle, they will move to the main portion of the lesson, in which they build tetrahedrons.</p> <p>Each group gets a copy of the Tissue Paper Template.</p> <p>Constructing one tetrahedron involves the following steps: https://web.archive.org/web/20150321015402/http://illuminations.nctm.org/Lesson.aspx?id=2121</p> <p><i><u>See Student Straw Form Directions below for detailed pictures.</u></i></p> <ol style="list-style-type: none">1. String three straws on the 40" string. Tie the string so that the three straws form a tight triangle. It is important that one end of the remaining string be long enough to pass through another straw. The easiest way to pass the string through the straw is to start the string into the straw and then suck the string through the straw.2. Tie an end of each of the two short strings to the vertices where there is no knot. Then, pass each string through a straw and tie the ends together to form a tight triangle. The five straws should now form a rhombus with one diagonal, as shown below.3. Pass the long string through the last straw and connect it to the opposing vertex to form a tetrahedron. Tie the ends together to complete the shape.4. Fold a 20" × 26" piece of tissue paper into fourths, as shown. Each quarter will be 10" × 13" and is enough to cover two faces of the tetrahedron. Fold the 10" × 13" pieces into fourths, and place the template on two folded edges. Cut along the three sides marked CUT. (Students should place the template and make the three cuts while the tissue paper is still folded. This will prevent unnecessary cutting, and the proper shape will result when the paper is unfolded.)5. Unfold each quarter. They will look like this:6. Attach the tissue paper to two faces of the tetrahedron. Lay the tissue paper on the table. Put glue along the flaps, and fold the flaps over the straws. Rotate the tetrahedron, apply glue to the other flaps, and fold these flaps over the straws. Call the resulting shape Tetrahedron 1. Tell students that the edge length is one straw, the area of a face is one triangle, and the

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	<p>volume is one tetrahedron.</p> <ol style="list-style-type: none">7. Have students combine four copies of Tetrahedron 1 to make a larger tetrahedron. Place three tetrahedra on the table as shown, and tie the adjacent base vertices together.8. Place the fourth tetrahedron on top of the other three, and tie the adjacent vertices. Make the joints tight with no slack in the string for a sturdier model. Call the resulting larger shape Tetrahedron 2. The final result will look like the figure shown below.9. Using 16 copies of Tetrahedron 1, or four copies of Tetrahedron 2, students can create a larger version of the tetrahedron model. <p>To help students determine the volume, have each group make four tetrahedron pieces and one octahedron piece. Use these pieces to make a tetrahedron with the octahedron in the center. This helps to verify that the open space in the center of Tetrahedron 2 is an octahedron. What is the volume of the octahedron in terms of Tetrahedron 1? Cut the octahedron into two square pyramids; then, cut one of the square pyramids in half by making the cut from the diagonal of the square base to the opposite vertex creating two triangular pyramids each made up of two isosceles right triangles and two equilateral triangles. Compare the equilateral bases and the heights of the tetrahedron and the triangular pyramid. What can you say? The triangular bases and heights of the tetrahedron and the triangular pyramid are equal. What can you say about the volumes of these two pieces? The volumes are also equal. What can you say about the volume of the octahedron? The volume of the octahedron is equivalent to four times the volume of Tetrahedron 1, so the volume of Tetrahedron 2 is equivalent to eight times the volume of Tetrahedron 1.</p> <p><u>Tetrahedral Kites</u> https://web.archive.org/web/20150321015402/http://illuminations.nctm.org/Lesson.aspx?id=2121 <u>Tissue Paper Template.</u> http://illuminations.nctm.org/uploadedFiles/Content/Lessons/Resources/9-12/Tetrahedron-AS-Tissue</p>

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	<p>Template.pdf Directions for Making a Tetrahedral Kite http://mathandecon.ncee.net/35/visuals/lesson7_activity.pdf</p> <p>Constructing one tetrahedron involves the following steps: https://www.youtube.com/watch?v=SRNorfpir2c</p>
<p>Evaluate The purpose for the EVALUATION stage is for both students and teachers to determine how much learning and understanding has taken place.</p>	<p>Objectives Students have collected support artifacts and will display their digital stories in small groups. Students will present their final kite design to support the digital story. Students will archive their digital stories in a form that can be used in future school years. Students will analyze and critique the variations in kite design. They must formulate their analysis in terms of evidence presented in the digital stories.</p> <p>Analysis of Manufacturing Gather the class for a concluding discussion. Ask the following investigating questions:</p> <ul style="list-style-type: none">• How well did your team work together to build your kite? Were you efficient? Where was time wasted? What were the problems?• Which improvement made for the largest difference in flight time?• Did you follow the specific instructions and use the specified materials? Did you finish on time? How was the quality of the end product?• Describe all the basic manufacturing system processes you used (cutting, shaping, forming, conditioning, assembling, joining, finishing, and quality control).• What improvements would you make to the kite-making process?

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	<ul style="list-style-type: none">• What is industrial engineering? (After listening to student suggestions, read the definition.) How is the kite-making your team did in this lesson a type of industrial engineering?

Assessment

1. Diagnostic Forces of flight Pre-Test in Testmoz located at: testmoz.com/700418 passcode:83

2. Formative [Length, Area, and Volume Sheet](#)

Exit Tickets using the App [Plickers](#):

1. After you have your completed three-dimensional object it will have four congruent equilateral triangular faces.

Draw the object that is formed. What is the name of this shape?

2. How many kites would be needed to a construct a stage 1 kite?

3. Write a function that would allow you to predict the number of stages in a stage 3 kite.

Would we have enough students in our class to produce this kite?

4. What tools (human and innate) would you use to determine the exact height of your kite?

5. Draw a figure that represents the angles needed for this height determination.

Observation of participation in discussions and daily progress, Fist to Five, Thumbs up/Thumbs down, Journal Entries

3. Summative: Students will demonstrate and communicate their learning of [Kite Science](#) through a digital story answering 3-4 of the essential questions. The story must include a description of that explains why kites fly. Narrative must include pictorial and verbal depiction of lift, drag, gravity, dihedral, equilibrium, and flight stability.

Essential questions

1. How are the forces on a kite identical to forces on an airplane? Use [kite geometry](#) to develop a model that explores the relationship between lift and weight and thrust and drag for a tetrahedron kite.

2. Use [lift equations](#) to make a prediction of the lift of your kite. Then compare your prediction of lift to the [KiteModeler](#).
Use [drag equations](#) to make a prediction of the lift of your kite. Then compare your prediction of lift to the [KiteModeler](#).
What [trigonometric relationships](#) are employed to determine the altitude of a flying kite?

3. What are the linear, area, and volume measurements using non-traditional units of measure for a student-constructed tetrahedron?
4. After combining four tetrahedra from a similar tetrahedron describe the linear dimensions and how they compare to the original tetrahedron. Explore and then develop a generalization for the area and volume between the first and second tetrahedra.

4. Public Presentation to people beyond their classmates and teacher to include in class archive

Students in a team of 3-4 will plan a way to explain their tetrahedron kite design experience to the whole group. They may utilize any part of their digital story to illustrate the impact of their process. They will connect their explanations to airplane flight and the aerodynamic forces exerted on a kite in flight.

Forces on a Kite Rubric

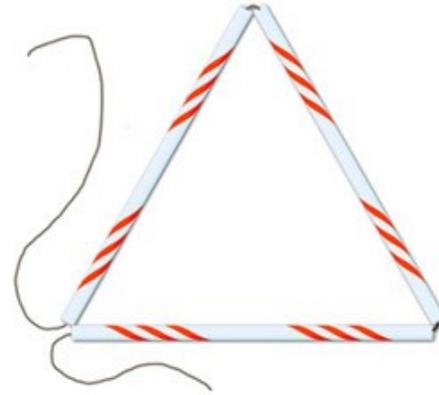
Name: _____ Date: _____ Kite # _____

Category	5 Exemplary	4 Distinguished	3 Proficient	2 Basic Competency	1 Needs Improvement	0 Insufficient
1. Blueprint of kite designed on graph paper	Blueprint is drawn neatly and precisely with a well-thought out design.	Blueprint is drawn neatly with a thoughtful design but has a few inaccuracies.	Blueprint is drawn neatly but the design has some flaws.	Blueprint is drawn but is sloppy and design has some flaws.	Blueprint is drawn but is difficult to read and design contains significant flaws.	No blueprint of kite.
2.Craftsman ship, creativity, neatness of construction	Kite is creative, well-constructed, attractive, and durable, and can be flown repeatedly.	Kite is well-constructed and durable, and can be flown repeatedly.	Effort is shown; kite will stand up to being played with more than once.	Kite is neat in construction but modifications must be made to be effective. Kite may be flown once.	Kite is messy and uncreative. Insufficient effort on design craft.	No kite is constructed.
3.Flight performance	Kite flies at least 10 feet above the ground for at least 10 seconds.	Kite flies at least 10 feet above the ground for at least 5 seconds.	Kite flies at least 5 feet above the ground for at least 3 seconds.	Kite flies as student runs while pulling the string for 5 seconds.	Kite flies as student runs while pulling the string for 3 seconds.	Kite does not fly.
4.Kite constructed according to blueprint	Kite is constructed according to design on blueprint with accurate side lengths according to scale factor.	Kite is constructed according to design on blueprint but with some inaccuracies.	Kite is similar to design on blueprint with several inaccuracies.	Kite is similar to design on blueprint but measurements and scale factor are wrong.	Kite is constructed but does not resemble blueprint design.	No kite is constructed.

5. Digital story design process	Student is able to define, identify, and communicate design process of the kite. Story is creative, functional, and personalized	Provides correct full list of the major materials. Describes their use, and includes pictures that clearly depict initial and final design of kite.	Identifies all materials. Includes pictures that depict initial and final design of kite.	Partially describes materials. Includes at least one picture of initial or final design.	Inadequately or inaccurately describes materials used. Does not include any visual representation of their design.	No description of design process.
6. Digital story flight video	Attractive video with exceptionally neat, clear, and steady picture; audible sound; and small enough to email file. Includes estimate of kite altitude.	Attractive video with exceptionally neat, clear, and steady picture; audible sound; and small enough to email file.	Attractive video that is adequately neat and clear.	Video is acceptably attractive, but parts are messy and/or unclear.	Video is distractingly messy and unattractive in layout and design.	No Video.
					Total	/30

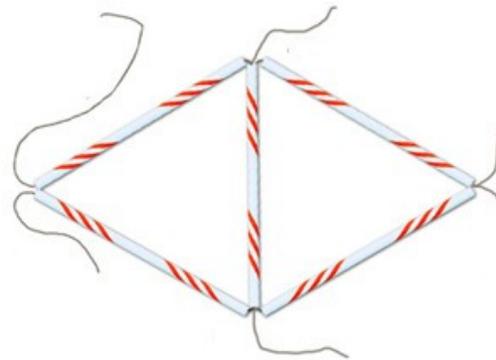
Student Straw Form Directions

1. String three straws on the 40" string. Tie the string so that the three straws form a tight triangle. It is important that one end of the remaining string be long enough to pass through another straw. The easiest way to pass the string through the straw is to start the

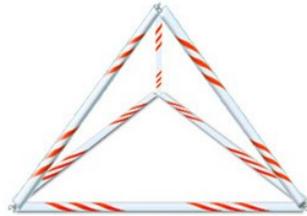


string into the straw and then suck the string through the straw.

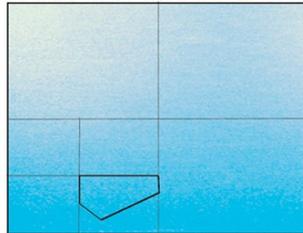
2. Tie an end of each of the two short strings to the vertices where there is no knot. Then, pass each string through a straw and tie the ends together to form a tight triangle. The five straws should now form a rhombus with one diagonal, as shown below.



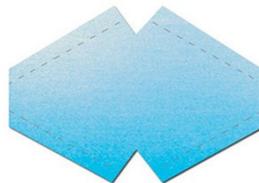
3. Pass the long string through the last straw and connect it to the opposing vertex to form a tetrahedron. Tie the ends together to complete the shape.



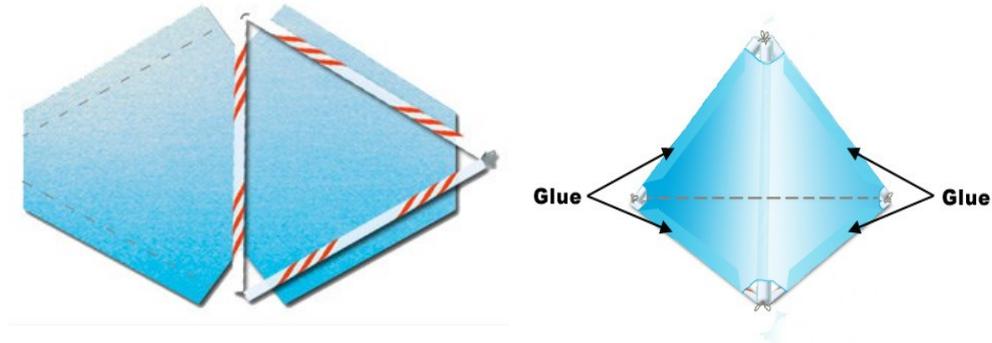
4. Fold a 20" × 26" piece of tissue paper into fourths, as shown. Each quarter will be 10" × 13" and is enough to cover two faces of the tetrahedron. Fold the 10" × 13" pieces into fourths, and place the template on two folded edges. Cut along the three sides marked CUT. (Students should place the template and make the three cuts while the tissue paper is still folded. This will prevent unnecessary cutting, and the proper shape will result when the paper is unfolded.)



5. Unfold each quarter. They will look like this:

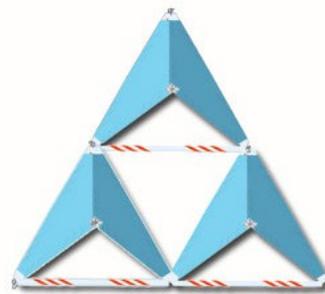


6. Attach the tissue paper to two faces of the tetrahedron. Lay the tissue paper on the table. Put glue along the flaps, and fold the flaps over the straws. Rotate the tetrahedron, apply glue to the other flaps, and fold these flaps over the straws.

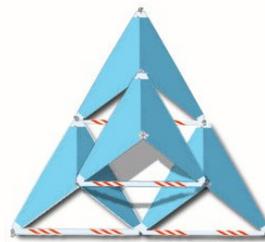


Call the resulting shape Tetrahedron 1. The edge length is one straw, the area of a face is one triangle, and the volume is one tetrahedron.

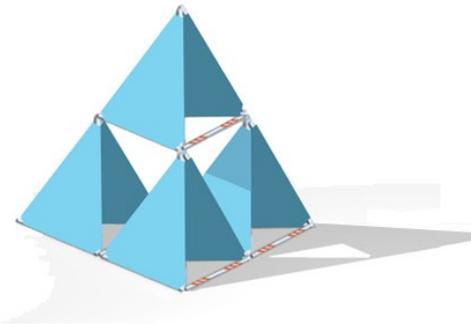
7. Combine four copies of Tetrahedron 1 to make a larger tetrahedron. Place three tetrahedra on the table as shown, and tie the adjacent base vertices together.



8. Place the fourth tetrahedron on top of the other three, and tie the adjacent vertices. Make the joints tight with no slack in the string for a sturdier model.



Call the resulting larger shape Tetrahedron 2. The final result will look like the figure shown below.



Using 16 copies of Tetrahedron 1, or four copies of Tetrahedron 2, students can create a larger version of the tetrahedron model. Adapted from:
<https://illuminations.nctm.org/Lesson.aspx?id=2121>

Sources

Bell, A.G. 1903. The tetrahedral principle in kite structure. National Geographic 44: 219–251. Retrieved 7/1/18 from <http://lcweb2.loc.gov/mss/magbell/377/37700202/37700202.pdf>

Inman, D. (1997). Water Rockets and Indirect Measurement. Science Scope, 20(7), 22-23. Retrieved from <http://www.jstor.org/stable/43179622>

King, K. (2004) Ever Fly a Tetrahedron? Retrieved on 7/1/18 from: <http://www.nsta.org/publications/news/story.aspx?id=49092>

King, K. (2002) Teaching physical science in the outdoors: Using flying objects to teach physical science concepts and the process of inquiry. Retrieved on 7/1/18 from:

https://web.archive.org/web/20041214165044/http://www.cedu.niu.edu:80/scied/courses/tlci525/sample_unit.htm

Froschauer, L. editor. (2010). The frugal science teacher, 6-9, strategies and activities. [Arlington, Va.] :NSTA Press Retrieved on 7/1/18 from https://books.google.com/books?id=v2ih_tFJpkC&pg=PA13&lpg=PA13&dq=instructions+for+building+an+astrolabe+April+1997+

[+Science+Scope&source=bl&ots=d4gP34Iqzb&sig=SuSYDysqaZ_9UWgb_VjRF22Qkh8&hl=en&sa=X&ved=0ahUKEwi9-OansP7bAhVypVkKHchuCsAQ6AEIjAA#v=onepage&q=instructions%20for%20building%20an%20astrolabe%20April%201997%20%20Science%20Scope&f=false](https://books.google.com/books?id=v2ih_tFJpkC&pg=PA13&lpg=PA13&dq=instructions+for+building+an+astrolabe+April+1997++Science+Scope&source=bl&ots=d4gP34Iqzb&sig=SuSYDysqaZ_9UWgb_VjRF22Qkh8&hl=en&sa=X&ved=0ahUKEwi9-OansP7bAhVypVkKHchuCsAQ6AEIjAA#v=onepage&q=instructions%20for%20building%20an%20astrolabe%20April%201997%20%20Science%20Scope&f=false)

Robin, B. (2006, March). The educational uses of digital storytelling. In *Society for Information Technology & Teacher Education International Conference* (pp. 709-716). Association for the Advancement of Computing in Education (AACE). <https://web.archive.org/web/20120410135406/http://digitalstorytelling.coe.uh.edu/>