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Hoop Glider Design Challenge

The Tech Challenge 2016 Flight Lesson 4:
Developed by The Tech Academies of Innovation

I. Lesson Overview

How does changing the size of the glider's hoops affect flight characteristics?

Lesson Description: Students will design and launch a hoop glider to soar through the air! Students will test and observe flight characteristics of gliders and then use fractions (4^{th} -5^{th}) or ratios and proportions (6^{th} -8^{th}) to design the ultimate glider!

Grade Levels: 4-8

Education Outcomes:

Students will:
- build prototype gliders and observe the effects of hoop size on flight characteristics
- [4-5^{th}] use unit fractions to determine which fraction results in the longest flight distance.
- [6-8^{th}] use ratio and proportions to determine the ratio that results in the longest flight distance.

Education Standards

Met: (Note: bolded parts of the standards are fully met by this lesson)

Common Core Standards:

Math
- 4.NF.B.3 Understand how to **build fractions from unit fractions** by applying and extending previous understandings of operations on whole numbers.
- 4.NF.A.2 **Compare two fractions** with different numerators and different denominators, e.g., by creating common denominators or numerators, or **by comparing to a benchmark fraction such as ½ .** Recognize that comparisons are valid only when the two fractions refer to the same whole. Record the results of comparisons with symbols >, =, or <, and justify the conclusions, e.g., by using a visual fraction model.
- 6.RP.A.1 Understand ratio concepts and **use ratio reasoning to solve problems**.
- 7.RP.A.2.C **Represent proportional relationships by equations.**

Addressed: (The following standards are practiced in this lesson but are not explicitly taught and assessed)

NGSS Disciplinary Core Ideas (DCI)

3-5-ETS1.A: Defining and Delimiting Engineering Problems
- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

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3-5: PS2.A Forces and Motion

- The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.

NGSS Science and Engineering Practices (SEP):

3-5 SEP 1: Asking Questions and Defining Problems

- Ask questions about what would happen if a variable was changed.

6-8 SEP 1: Asking Questions and Defining Problems

- Ask questions to determine relationships between independent and dependent variables and relationships in models.

3-5 SEP 3: Planning and Carrying Out Investigations

- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.

NGSS Crosscutting Concepts (CCC):

3-5-CCC 6. Structure and Function - The way an object is shaped or structured determines many of its properties and functions.

- Different materials have different substructures, which can sometimes be observed.
- Substructures have shapes and parts that serve functions.

6-8-CCC3. Scale, Proportion, and Quantity - In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

- The observed function of natural and designed systems may change with scale.
- Scientific relationships can be represented through the use of algebraic expressions and equations.

Common Core Standards:

Mathematical Practices

- MP1 Make sense of problems and persevere in solving them.
- MP3 Construct viable arguments and critique the reasoning of others.
- MP4 Model with mathematics.
- MP6 Attend to precision.

English Language Development Standards:

Part 1A.1: Exchanging information and ideas with others through oral collaborative conversations on a range of social and academic topics

Part 1C.11: Supporting opinions or justifying arguments and evaluating others' opinions or arguments

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II. Advanced Prep & Set-Up for Lesson

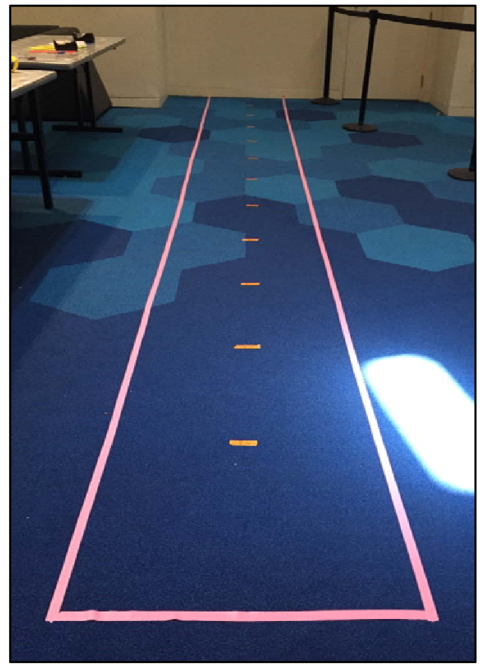
Hoop Size Test Advanced Set-Up

Materials (per pair of students)

- 2 strips of cardstock (1"x 10")
- 1 straw (standard drinking straws, non-bendy)
- 4" tape (Scotch or masking)
- 1 pair of scissors
- 2 landing markers such as Post-it Notes
- [6-8th only] 1 ruler (inches and centimeters)

Materials for launching area (for entire class)

- Tape for the floor (blue or masking)
- Tape measure
- An area at least 25 feet in length, free of furniture



Hoop Size Test Set-Up

1. Set up launching station:
   - Launching area should be inside to prevent air turbulence from affecting flight path of gliders.
   - Mark off and designate a long open area of at least 25 feet in length. It may be helpful to use furniture to physically separate this area so that launches are controlled.
   - Mark floor in 2 foot increments using the tape measure.
   - Indicate a clear 'launching' area for students to stand in.

2. Set up work space:
   - Cut cardstock into strips, 10 inches long and approximately 1 inch wide, enough for each pair to have at least 2
   - Pairs will each need a work space.
   - Either set up a supply station or have supplies at each work station. Because supplies are minimal for the first design challenge, you might pass out materials students will use for the first design challenge, and use a supply table for material selection in the second design challenge.

3. Data Collection
   - Create a large data collection chart on butcher paper to record data as gliders are being tested. Details that will be charted will include flight distance and flight characteristics ("Data Collection Table – Hoop Size Test 4-5th)" and "Data Collection Table – Hoop Size Test (6-8th)," Appendix C)
   - Teams will also be collecting data on their own copy of the data chart.
   - Sample data charts for each grade range with sample data are below:

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Hoop Size Test (Grades 4-5)

Team	Large Hoop	Small Hoop	Flight Distance	Flight Description
Directions:	*The large hoop will always be 1 whole!*	*Use your fraction strips to measure*	*How far from the launch does the glider land?*	*For example… Did it fly straight? Did it land right side up?*
Example:	*1 whole*	*1/3*	*15 feet*	*The glider flew to the left and flipped a few times in flight*

Hoop Size Test (Grades 6-8)

Team	Small Hoop	Large Hoop	Ratio of Small to Large Hoop	Flight Distance	Flight Description
Directions:	*The large hoop will always be 1 whole!*	*Use your fraction strips to measure*	*Be sure to simplify the ratio!*	*How far from the launch does the glider land?*	*For example… Did it fly straight? Did it land right side up?*
Example:	*3 inches*	*10 inches*	*3:10*	*9 feet*	*The glider flew straight but flipped many times during flight*

Modified Hoop Glider Challenge Advanced Set-Up

Materials (per pair of students)

- Strips of cardstock (1”x 10”) - 2+ (have extras available)
- Other materials to use for modified hoops. This may include the following but can be modified to what you have on hand:
  - Regular weight paper
  - Wax paper
  - Foil
  - Any other material that may be cut and curved to make a hoop
- Straws (standard drinking straws, non-bendy) - 1+ (have extras available)
- Other types of straws to use for modified gliders. This may include:
  - Coffee stirrers
  - Large diameter straws (“Bubble Tea” type)
- Tape (Scotch or masking) - approx. 12”
- Scissors - 1
- [6-8th] Ruler - 1
- [4-5th] unit fraction strips (“Fraction Strips,” Appendix C)
- Landing markers, such as Post-it Notes - 2

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Modified Hoop Glider Challenge Set-Up

1. Use the same launching station set-up as in the Hoop Size Test activity.

2. Set up work spaces for pairs to work on their modified Hoop Gliders:
   - Each pair of students will need their own workspace. Tables or desks pushed together work well for this space.
   - Either set up one supply station for students to gather supplies from or have supplies divided up on the pairs' workspaces.

3. Data Collection
   - Create a large data collection chart on butcher paper to record data as modified gliders are being tested. These data will be charted on the second half of students' data chart as tests are performed *("Data Collection Table – Modified Hoop Glider Design," Appendix C)*
   - A sample data chart with sample data is below.

Modified Hoop Glider Design Challenge

Team	Description of modifications	Distance Glider Travelled	Flight Description (How did it fly?)
Directions:	*Describe what this group did to modify their glider – what did they add, change, take off?*	*Measure in feet or meters.*	*For example...* *Did it fly straight?* *Did it land right side up?*
Example:	They added a third hoop in the middle that was in between the sizes of the two hoops and made all the hoops twice as wide.	17 feet	- The glider flew in a mostly straight line - The glider landed right side up, but it flipped two times during flight

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III. Hoop Glider Design Challenge Lesson Guide

Guiding Question: How does changing the size of the glider's hoops affect flight characteristics?

A. Introduction (5-10 minutes)

1. Review the concept of being engineers.
   - Specify that engineers use many mathematical concepts.

2. Introduce **aerospace engineering** by asking some guided questions to connect students' prior knowledge:
   - What do you think aerospace engineering means?
   - How do aircraft and spacecraft help our everyday life?
   - How do you think aerospace engineers might use math?

3. Address any misconceptions that students may have about aerospace engineering or engineering in general. Some misconceptions may include:
   - Students may think that aerospace means only outer space.
   - Students may only associate aerospace engineering with airplanes and 'classic' aircraft designs but aerospace engineering also includes other flying devices and improving airflow around many other objects including vehicles, soccer balls, buildings, and more.

> **Facilitator Notes:**
> Introduction
> - This lesson is a great way to culminate a unit on fractions (4^{th} -5^{th}) or ratios and proportions (6^{th} -8^{th}), allowing students to apply their knowledge to an engineering design challenge.
> - **Aerospace engineering** is a field of engineering that works mainly with developing aircraft and spacecraft.
> - Possible Answers to Guided Questions might include:
>   - Engineers work to find solutions for problems in society.
>   - Aerospace engineers make safe and reliable aircraft and spacecraft.
>   - Engineers use math to determine sizes and make predictions about products.
>   - Engineers use math to make calculations and measurements.

B. Hoop Size Test (45-60 minutes)

1. Introduce the model of the **prototype** hoop **glider** design.
   - Why do you think this model is called a glider vs. an airplane?
   - What do you notice about the glider?
   - How is this glider similar to an airplane? How is it different?
   - What are the different parts of the hoop glider?
   - What do you notice about the materials used?

2. Discuss the student definitions of prototype and glider. A **prototype** is a first model of something, from which other forms are developed or copied. A **glider** is an aircraft without an engine.

3. Introduce the Hoop Size Test to the students by describing the following experimental guidelines:

   <u>Design Problem</u>:
   - NASA is exploring new ways to explore the atmospheres of nearby planets. NASA would like to investigate dropping small, unmanned gliders that would be released from a spacecraft and would capture data on their way down through the atmosphere. The farther the

> **Facilitator Notes:**
> Glider introduction notes
> - Teachers may want to provide photos of gliders, hang gliders, and airplanes for the students to compare and contrast.
> - Before testing begins, teachers should have a discussion about launching safety and rules, as well as keeping the launching techniques the same to limit the variables.
> - Remind students that a glider won't always look the same as an airplane or bird, especially when thinking about wing shape.
> - Make sure students are aware that each hoop needs to be precisely placed on the straw for precision in throwing.
> - During launch, gliders do not necessarily need to be thrown with great force.
> - Students should be reminded that short flight distance does not equal failure. Emphasis should be placed on problem solving and perseverance.

distance traveled, the more data each glider could collect. NASA wants you to determine what fraction of the large hoop the small hoop should be [4th -5th] or what proportion there should be between the two hoops [6th -8th] in order to get the furthest flight.

Experimental question:

- [4-5th] When used as the front hoop, what fraction of the length of the whole strip allows for a Hoop Glider to fly the greatest distance?
- [6-8th] What ratio of the sizes of the front hoop to back hoop allows for a Hoop Glider to fly the greatest distance?

Control Variables:

- Each of the team's 2 gliders built with:
  - 1 straw
  - 2 hoops; 1 on each end of the straw
  - The same orientation of the hoops to the straw
- All gliders launched by the same person

Independent Variable:

- [4-5th] Different fractions of whole strip as the front hoop
- [6-8th] Different ratios between the two hoop sizes

Constraints (Design Limitations):

- Budget per glider: 1 straw, 2 strips of cardstock, 6" of tape
- Schedule: 12 minutes

Testing:

- Students will test their Hoop Glider one at a time in the launching area, with all Hoop Gliders launched by the same person, 3 times each.
- As the class observes the gliders, for each glider record the furthest distance and observations of flight behaviors on their data collection charts *("Data Collection Table – Hoop Size Test* (4-5th)*" and "Data Collection Table – Hoop Size Test* (6-8th)*," Appendix C*).

Facilitator Notes:
Possible misconceptions about fractions [4th -5th]

- Students need to be reminded that when a whole is cut into parts, those parts are less than a whole.
- When students are reading or writing fractions, they need to remember that a larger denominator does not mean that the fraction is larger (i.e. ¼ is larger than ½ because 4 is larger than 2)
- When students are adding fractions, they should not add the numerators and the denominators together (i.e. ½+⅔=⅗
- Students may mix up the numerator and denominator. Remind them that the **numerator** (the number on top) is the number of fractional units selected and the **denominator** (the number on the bottom) is the number of total parts in 1 whole – "D" for "Down"

Possible misconceptions about ratios [6th -8th]

- When students are writing ratios, they need to remember that the order of numbers matter and that 5:10 is not the same as 10:5.
- When students are writing a ratio, remind them to reduce to the simplest term.
- Remind students that ratios can be written three different ways, for example 1:2, 1 to 2, and ½.

Facilitator Notes:
Experimental design

- This portion of the lesson, *Hoop Size Test*, is an experiment rather than a design challenge. An experiment is a test of an idea and includes constants that are controlled and one variable that is being tested. A design challenge is an open-ended project that encourages participants to ask questions, think creatively, and try many different ideas.
- For more information about experiments, look at *The Tech Challenge 2016 Aero Lesson 3 – Engineering Takes Flight*, particularly part B of the lesson plan *(see here or in appendix B)*

4. Instruct students on how to build the prototype design. Use the Hoop Glider Instructions handout, giving one to each pair *("Hoop Glider Instructions," Appendix C)*
   - Before students start building, ask them to predict how they will work together to build the glider.
     - How is having two people going to be helpful for building the glider?
     - How can you make sure that both members of the team share the work?
     - How can you solve disagreements as you're building?

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5. Monitor student pairs as they build their gliders.
   - Ensure that each pair is using one straw and two hoops for each of their gliders and are making two gliders with different fractions [4-5th]/ ratios [6-8th] to test.
   - Check that one hoop is smaller than the other
   - Monitor to ensure that students are using collaboration to share the workload and that 4 hands and 2 brains are used throughout the construction process.
   - Possible questions, you might ask while students work include:
     - How did you figure out how long to make your smaller hoop?
     - How do you predict your glider will fly? Why do you think so?
     - How did you decide to divide up the work? What ideas did each of you contribute?

6. Test the prototype with all students
   - As teams are finishing, they may come up to the launch area to pre-test their glider.
   - When time is called, have teams gather at a safe distance around the launch area.
   - Choose a student launcher to test gliders. Explain to students that one launcher is chosen to try to limit the variables in order to ensure a **fair test**. Explain to students that one launcher is chosen to try to control as many variables as possible as we learned is important in Lesson 3: "Engineering Takes Flight" *(see here or in Appendix B)*.
   - The launcher will test each hoop glider 3 times.
   - Mark each test flight's distance on the ground with a post-it note or other marker.
   - The furthest distance will be recorded on the class Data Collection Chart *("Data Collection Table – Hoop Size Test (4-5th)" and "Data Collection Table – Hoop Size Test (6-8th)," Appendix C)*
   - Teams should be observing for flight behaviors and recording them on their own data chart *("Data Collection Table – Hoop Size Test (4-5th)" and "Data Collection Table – Hoop Size Test (6-8th)," Appendix C)* as well. Give examples as to what behaviors to look for: curved flight path, flipping or spinning during flight, how the glider lands, and other motions or movements during the flight that students find interesting.

Facilitator Notes:
Launching and testing gliders
- Before testing begins, teachers should have a discussion about launching safety and rules, as well as keeping the launching techniques the same to limit the variables.
- Flight characteristics may include flight stability (flips, spins), distance, flight orientation (top up, sideways), or flight path (left or right of the straight path).

Facilitator Notes:
Guiding questions
- Use sentence stems to help students structure their ideas and responses:
  - "I observe each glider____"
  - "During the test, many gliders flew_______"
  - "My hypothesis is that this is caused by_______. This is based on my observations of _________"
  - "I disagree with _____'s hypothesis, I believe that this is caused by_______. This is based on my observations of __________"

C. Content Learning (45-60 minutes)

1. Give each team a new strip of paper to serve as their 1 whole. Fold strip in half and open. Leave strip on desk. Discuss with students what fraction this represents.
   - What did we do to the whole strip?
   - How could you describe the parts we folded the whole into?

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2. [4-5th] Discuss the concept of a **benchmark** with students. A benchmark is a fraction that acts as a point of comparison for other fractions. The major benchmarks used for fractions are 0, ½, and 1.
   - Discuss with students:
     - Why do you think we use ½ as a benchmark?
     - How can you compare fractions to ½?
     - How can keeping a benchmark in mind help you think about fractions?
   - Benchmarks are helpful for comparing fractions in many ways:
     - Fractional equivalents to 0, ½, and 1 are easily found with all denominators. You can quickly tell if a numerator is more or less than half of a denominator, letting you get a sense of where that fraction lies in relation to a size that is easy to visualize. 1 whole is also easy to visualize no matter the denominator, thinking about when the numerator matches the denominator.
     - Placing fractional values on a number line in comparison to 0, ½ and 1 is simple for students who are still working to compare fractions with unlike denominators. If one fraction is larger than ½ and another is smaller, it is easy to visualize that the first fraction is larger than the second.
     - Comparing to benchmarks gives students an easily accessible self-check and error analysis to do on their own work and allows them to internalize answering the questions “Does this answer make sense?”

3. [4-5th] Review building fractions from unit fractions. Teachers may want to use unit fraction strips to help students’ understanding *(“Fraction Bars,” Appendix C)*

4. [6-8th] Review the important aspects of ratios and proportions with students. Be sure to discuss the ways to write a ratio and the importance of the order of the numbers within the ratio, as well as writing ratios and proportions from data.
   - Writing ratios for a given scenario can be as simple as counting or measuring.
     - A "ratio" is just a comparison between two different things. For instance, someone can look at a group of people, count noses, and refer to the "ratio of men to women" in the group. Suppose there are thirty-five people, fifteen of whom are men. Then the ratio of men to women is 15 to 20.
     - Notice that, in the expression "the ratio of men to women", "men" came first. This order is very important, and must be respected: whichever word came first, its number must come first. If the expression had been "the ratio of women to men", then the numbers would have been "20 to 15".
   - Ratios can be expressed in three ways – in words (15 to 20), with a colon (15:20), and fractionally (15/20)
   - A proportion is two ratios that have been set to be equal to each other – a proportion is an equation that can be solved. Ratios in proportions are usually written as fractions, as this makes it easier to visualize both the equivalent nature of the ratios as well as how you solve the equation for a missing value.

5. [6-8th] Have students find some ratios around the classroom and solve some proportions for missing values:
   - What is the ratio of desks to chairs in the room?
   - If that ratio is always true, how many chairs would there be in 4 classrooms if there were [#] desks total?
   - What is the ratio of female students to male students? The ratio of female students to *total* students?

6. Have students carefully take the small hoop off of their glider.

7. With scissors, students should make one cut to cut the hoop open.

Facilitator Notes:
Vocabulary
- It may be helpful for teachers to create a math vocabulary word wall in the classroom for students to use during class discussions. Teachers may want to offer an incentive for use of academic vocabulary throughout student conversations.
- When discussing hoop sizes with grades 6-8, support students in using vocabulary related to ratios and proportions.

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8. [4-5th] Determine whether the small hoop is less than the benchmark fraction ½, about ½, or greater than ½ by comparing it to the folded whole strip.
   - [4-5th] How do you know that your strip is shorter, about the same, or longer than ½?
   - [4-5th] How can benchmark fractions help us **estimate** (give a general idea about the value, size or cost of a quantity) our fraction's size more easily or compare different fractions to each other?

> **Facilitator Notes:**
> Sentence Frames for Content Questions
> - "The reason I estimate that the strip is less than ½ (about ½, greater than ½) is because ________."
> - "Benchmark fractions make estimating easier because __________."
> - "The hoop gliders that flew the greatest distance had a smaller hoop fraction/ratio of ________."

9. Have a class discussion about the gliders and their flight performance. During the discussion, guide students to observations of the hoops that include mathematical descriptions including fractions [4-5th] and ratios [6-8th]
   - What did you notice about the size of the hoops?
   - Were there similarities between hoop sizes of gliders that flew a long distance versus a short distance?
   - Mathematically, how can we compare the hoop sizes? (i.e. ⅔ of 1 whole, ratio of 1:2)
   - [4-5th] The gliders that went the furthest have a small hoop of which fraction?
   - [6-8th] What similarities do you see between the gliders that go the furthest in their **ratios** (a comparison of two quantities)?

> **Facilitator Notes:**
> Flight Performance discussion
> - Students should notice that the gliders that performed the best had hoops that were close to a ratio of 1 to 2.
> - With 4-5th grade, students should notice that when the front hoop is closer to ½ of the back hoop, the glider's performance increased.
> - With 6-8th grade, student should notice that when the ratio of the front to back hoop of the glider is close to 1:2 when reduced/simplified, the glider's performance increased.

10. Help students examine the data from the Hoop Size Test to determine what fraction [4-5th] or ratio [6-8th] performed the best.
   - Testing during development of the lesson showed that having a front hoop that is ½ of the larger hoop [4-5th] or a ratio of front to back hoops of 1 to 2 [6-8th] gave the best flight distance.
   - Your data may not match this exactly, but should give you similar conclusions.
   - The more trials you do during the first experiment the more your data should trend towards the above size relationships.

D. Modified Hoop Glider Design Challenge (45-60 minutes)

1. Review findings from the data charted in the Hoop Size Test Design Challenge.
   - Think back to your prototype glider's flight. Discuss with your partner what happened during testing.
   - What might be some things you could do to improve the flight? Think-Pair-Share and chart ideas.

2. Introduce the Modified Hoop Glider Design Challenge
   - Teams will be challenged to redesign and **iterate** their prototype hoop glider for "better performance". Explain to students that engineers are constantly rethinking and revising their designs in order to improve them.
   - [4-5th]:
     - Teams should keep one strip uncut to serve as 1 whole.
     - Using the conclusions about the best fraction for the first hoop, students should build on this idea to modify a glider that starts with the ideal fractional size of the small hoop.

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- [6-8th]:
  - Teams should use a ruler to measure the first strip.
  - Using a proportion, teams should determine the length of the second strip needed to fit the ideal ratio found in the Hoop Size Test.
  - Using different length strips for the large hoop and solving proportions could allow students to keep the same ideal ratio but change the sizes of their hoops.

3. Tell students that they are going to have a chance to think creatively about ways they might improve the Hoop Glider. Explain that brainstorming is a great way to gather ideas before you start working, and lead them in a brainstorm about different ways they could modify a glider that has the ideal fraction [4-5th] or ratio [6-8th]
   - Be sure to help students keep an open mind as they brainstorm (see rules for brainstorming in the Facilitator Notes on this page).
   - Some ideas that may come up:
     - Change the width of the strips being used for the hoops
     - Change the length of the straw
     - Put the small hoop in the back of the glider
     - Add additional hoops
     - Add wing-type pieces of paper
     - Use a different material for the hoops
     - Use wide "Bubble Tea" type straws instead of regular diameter straws
     - Make a double-decker hoop glider

Facilitator Notes:
Ideas for brainstorming while building:
- Brainstorming rules:
  - Suspend Judgement
  - Go for quantity
  - Be concise!
  - Capture all ideas
  - Go for wild ideas
  - Build on ideas of others
  - Be visual, sketch
  - Focus on the topic
  - All ideas are valid
- Give students a post-it and ask them to think of as many different variables as they can to change on their hoop gliders. Post the post-it notes on the board and celebrate overall class ideas and knowledge. Once students adapt their glider for test 2, they are welcome to keep modifying their gliders in innovative

Design Problem:
- NASA is investigating the Hoop Glider as a possible new aircraft for studying atmospheres on other planets. They want to gather as much information about the atmosphere of a planet as possible with each glider. Your task is to modify the simple Hoop Glider that they have been using to give it even more flight distance with each launch so it can gather more data for the scientists at NASA.

Criteria (Design Requirements/Desired Features):
- Each pair of students must build a glider using at least one straw and two hoops.
- The glider must travel 15 feet and stay on course without landing outside the launching area.
- All team members must contribute and must be able to articulate what their contribution was.

Constraints (Design Limitations):
- Budget: Teams may only use the materials provided.
- Schedule: 25 minutes.

Testing:
- Gliders will be launched by hand on the runway only.
- Gliders may not launch their gliders at anyone.
- Students will test their Hoop Glider one at a time in the launching area, with all Hoop Gliders launched by the same person, 3 times each.
- Have the class record the furthest distance and flight behaviors for each glider on the second part of their data collection chart ("Data Collection Table – Modified Hoop Glider Design Challenge," Appendix C).

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4. Be INNOVATIVE!
   - Give students the opportunity to change and adapt their glider however they wish. Some suggestions may be to change the shape of the attachments, change the length of the straws, add more attachments (shapes, wings, tail, etc.)

5. As teams are finishing, they may come up to the launch area to pre-test their glider.

6. When time is called, have teams gather at a safe distance around the launch area.
   - Teams should present their iterated glider before testing.
     - What structure did your team change from glider #1 to try to improve performance?
     - How did you change the structure?
     - Why did you make these changes?
     - What do you predict will happen when you test your glider? Why do you think this?
   - Choose a student launcher to test gliders. Explain to students that one launcher is chosen to try to limit the variables in order to ensure a fair test.
   - The launcher will test each hoop glider 3 times.
   - Mark each test flight's distance on the ground with a post-it note or other marker.
   - The furthest distance will be recorded on the class Data Collection Chart *("Data Collection Table – Modified Hoop Glider Design Challenge," Appendix C)*.
   - Teams should observe for flight behaviors and record them on their own data chart *("Data Collection Table – Modified Hoop Glider Design Challenge," Appendix C)*. Give examples of behaviors to observe (e.g. flipped in the air, landed upside down, etc.).

> **Facilitator Notes:**
> Sentence Frames for testing
> - "In our re-iteration, our team changed our design by ___________."
> - "We made these changes because _________."
> - "I predict our glider will______, because______."

7. Real World Application Discussion Questions:
   - Questions to ask to lead a discussion:
     - Why do you believe modern airplanes do not look like our hoop gliders?
     - Could our future airplanes look like our hoop gliders? Why or why not?
     - If we made these hoop gliders large enough to ride in, how large would they be?
     - Would these dimensions be ideal for flight? Why or why not?
   - Some responses may include:
     - Observations about the difficulty of carrying passengers or payload
     - Difficulty keeping the glider from flipping during flight
     - Questions about ways to steer the glider during flight
     - Questions about whether the gliders would still fly if scaled up to carry people
     - Depending on designs students come up with, there may be designs that would scale up to carry people or payloads better than others. Possibly discuss the pros and cons of different designs if we were trying to build an aircraft to carry people.

8. Assess students on their application of fractions (4-5th) or ratios [6-8th] using the assessment *("Hoop Glider Assessment," Appendix C)*

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IV. Appendices

A. Vocabulary

The following is the start of a suggested list of words to discuss as you read and discuss with students.

aerospace engineering	Field of engineering mainly concerned with developing aircraft and spacecraft.
benchmark fraction	A fraction that acts as a point of comparison for other fractions, most commonly 0, ½, and 1.
common denominator	When two or more fractions have the same denominator (the number on the bottom) they have a Common Denominator.
controlled variable	In an experiment, the factor or condition that is constant and unchanged
denominator	The bottom number in a fraction which indicates how many parts the whole is divided into (e.g. the 5 in ⅗ names the unit as fifths)
drag	Friction of a fluid (air or water) acting to resist motion of an object through the fluid.
estimate	To give a general idea about the value, size, or cost of a quantity.
fair test	Engineers and other scientists conduct a fair test by making sure that only one variable is changed at a time while keeping all other conditions the same.
flight characteristic or behavior	Qualities exhibited by an aircraft, rocket, or other device in flight, such as a tendency to stall or to yaw, or an ability to remain stable at certain speeds.
force	A push or a pull that changes the motion of an object or causes it to change shape.
glider	An aircraft without an engine
gravity	The force that pulls objects towards each other. (Ex: Earth pulls objects towards its center of mass)

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iteration	Perform again or repeat
lift	The force that directly opposes the weight of a flying device and holds it in the air. Lift is a mechanical aerodynamic force produced by the motion of the airplane through the air.
numerator	The top number in a fraction which indicates how many parts we have (e.g. the 3 in $\frac{3}{5}$ indicates 3 fractional units are selected)
proportion	The relationship between the size, number, or amount of two things
prototype	A first model of something, from which other forms are developed or copied.
ratio	The relationship that exists between the size, number, or amount of two things and that is often represented by two numbers
thrust	The force which moves an aircraft through the air. Thrust is used to overcome the drag of a flying device and to overcome the weight of a rocket.
turbulence	Sudden, violent movement of air or water
unit fraction	A rational number written as a fraction where the numerator is one and the denominator is a positive integer (e.g. $\frac{1}{2}$, 1/3, etc.)
variable	Any factor, trait, or condition that can exist in differing amounts or types. An experiment usually has three kinds of variables: independent, dependent, and controlled. The independent variable is the one that is changed by the scientist.
whole	Equivalent to one, a complete set, two halves, three thirds, etc.

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C. Lesson Handouts

Name: ______________________________

Date: __________ Class: ______________

Hoop Glider Instructions [4-5th]

What you need:

- 2 strips of cardstock or stiff paper (10 inches by 1 inch)
- 1 non-bendable drinking straw
- Scissors
- Fraction Bars handout
- Pencil
- Tape

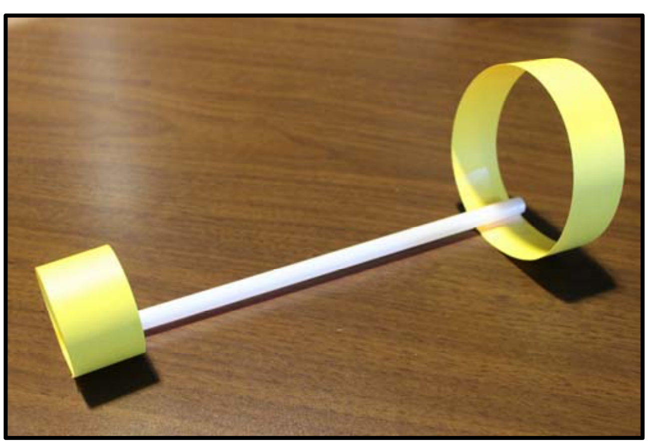
What to do:

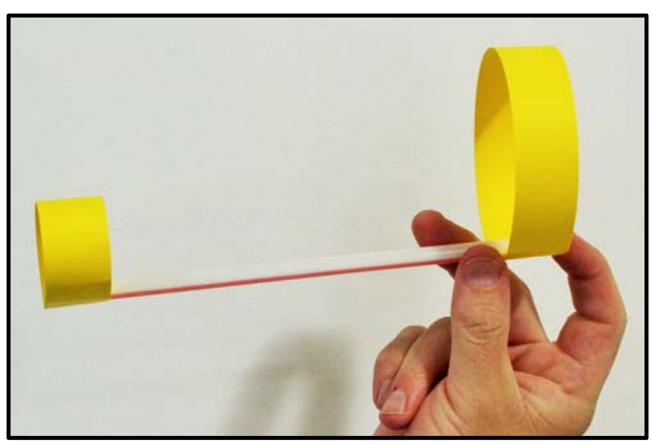
1. Take two strips of paper. Keep one strip whole, 1 inch wide and 10 inches long – to match the 1 whole on your fraction bars. The second strip should be cut in length to shorten it to match the fraction you are using for this glider.

2. Curl each strip into a hoop. Tape the ends together on each strip. Now you have two hoops of paper.

3. Tape the big hoop to one end of the straw. Tape the smaller hoop to the other end of the straw. Make sure the hoops line up.

4. Hold your Hoop Glider in the middle of the straw, with the small hoop in front. Throw it gently like a spear. It might take some practice to get the hang of it!





Name: ____________________________

Date: __________ Class: ______________

Hoop Glider Instructions [6-8th]

What you need:

- 2 strips of cardstock or stiff paper (10 inches by 1 inch)
- 1 non-bendable drinking straw
- Scissors
- Ruler
- Pencil
- Tape

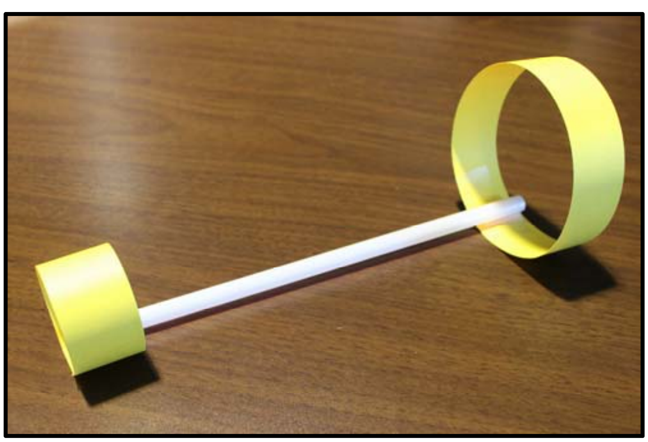
What to do:

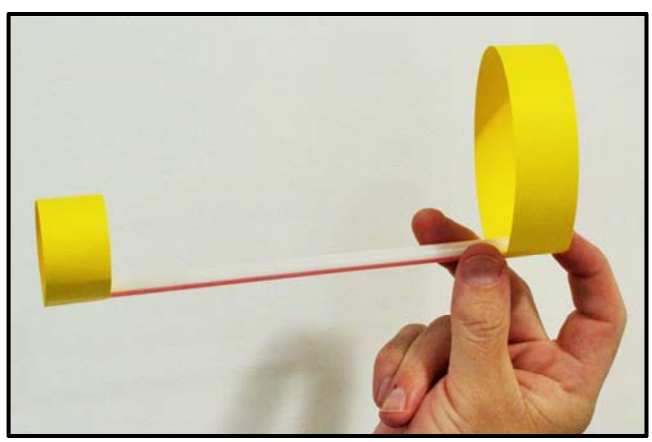
1. Take two strips of paper. Keep one strip whole, 1 inch wide and 10 inches long. Decide how long the strip should be for the shorter hoop in order to fulfill the ratio you are using for this glider. The second strip should be cut in length to shorten it to match that length.

2. Curl each strip into a hoop. Tape the ends together on each strip. Now you have two hoops of paper.

3. Tape the big hoop to one end of the straw. Tape the smaller hoop to the other end of the straw. Make sure the hoops line up.

4. Hold your Hoop Glider in the middle of the straw, with the small hoop in front. Throw it gently like a spear. It might take some practice to get the hang of it!





Name: ______________________________

Date: ___________ Class: ________________

Data Collection Table – Hoop Size Test [4-5th]

Team	Large Hoop	Small Hoop	Flight Distance	Flight Description
Directions:	*The large hoop will always be 1 whole!*	*Use your fraction strips to measure*	*How far from the launch does the glider land?*	*For example…* *Did it fly straight?* *Did it land right side up?*
Example:	*1 whole*	*1/3*	*15 feet*	*The glider flew to the left and flipped a few times in flight*
	1 whole	1/5		
	1 whole	2/5		
	1 whole	1/3		
	1 whole	3/8		
	1 whole	1/2		

Name: ______________________

Date: __________ Class: ____________

Team	Large Hoop	Small Hoop	Flight Distance	Flight Description
	1 whole	5/8		
	1 whole	2/3		
	1 whole	4/5		
	1 whole	3/4		
	1 whole	4/5		
	1 whole	9/10		
	1 whole	1		

Name: ______________________

Date: __________ Class: ____________

Data Collection Table – Hoop Size Test [6-8th]

Team	Small Hoop	Large Hoop	Ratio of Small to Large Hoop	Flight Distance	Flight Description
Directions:	*The large hoop will always be 1 whole!*	*Use your fraction strips to measure*	*Be sure to simplify the ratio!*	*How far from the launch does the glider land?*	*For example… Did it fly straight? Did it land right side up?*
Example:	*3 inches*	*10 inches*	*3:10*	*9 feet*	*The glider flew straight but flipped many times during flight*

Name: ______________________________

Date: __________ Class: ______________

Team	Small Hoop	Large Hoop	Ratio of Small to Large Hoop	Flight Distance	Flight Description

Name: ______________________________

Date: ___________ Class: ______________

Data Collection Table – Modified Hoop Glider Design Challenge

Team	**Description of modifications**	**Distance Glider Travelled**	**Flight Description (How did it fly?)**
Directions:	*Describe what this group did to modify their glider – what did they add, change, take off?*	*Measure in feet or meters.*	*For example…* *Did it fly straight?* *Did it land right side up?*
Example:	They added a third hoop in the middle that was in between the sizes of the two hoops and made all the hoops twice as wide.	17 feet	- The glider flew in a mostly straight line - The glider landed right side up, but it flipped two times during flight

Name: ________________________________

Date: ___________ Class: ________________

Team	Description of modifications	Distance Glider Travelled	Flight Description (How did it fly?)

Name: ______________________

Date: __________ Class: ______________

Fraction Bars

1

$\frac{1}{2}$ $\frac{1}{2}$

$\frac{1}{3}$ $\frac{1}{3}$ $\frac{1}{3}$

$\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$

$\frac{1}{5}$ $\frac{1}{5}$ $\frac{1}{5}$ $\frac{1}{5}$ $\frac{1}{5}$

$\frac{1}{6}$ $\frac{1}{6}$ $\frac{1}{6}$ $\frac{1}{6}$ $\frac{1}{6}$ $\frac{1}{6}$

$\frac{1}{7}$ $\frac{1}{7}$ $\frac{1}{7}$ $\frac{1}{7}$ $\frac{1}{7}$ $\frac{1}{7}$ $\frac{1}{7}$

$\frac{1}{8}$ $\frac{1}{8}$ $\frac{1}{8}$ $\frac{1}{8}$ $\frac{1}{8}$ $\frac{1}{8}$ $\frac{1}{8}$ $\frac{1}{8}$

$\frac{1}{9}$ $\frac{1}{9}$ $\frac{1}{9}$ $\frac{1}{9}$ $\frac{1}{9}$ $\frac{1}{9}$ $\frac{1}{9}$ $\frac{1}{9}$ $\frac{1}{9}$

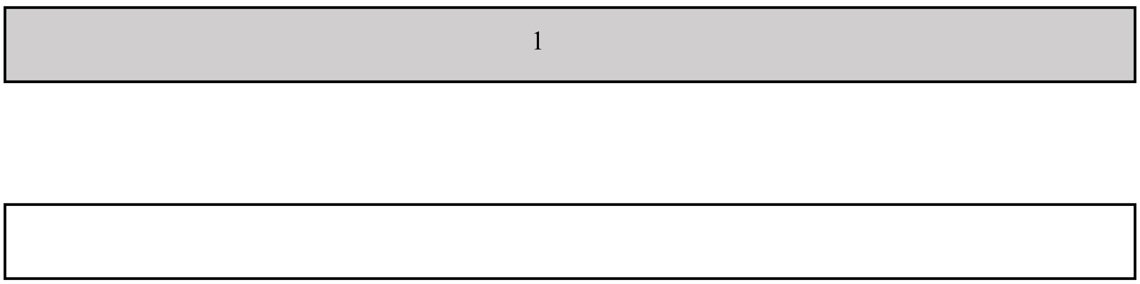
$\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$

Name: ______________________________

Date: __________ Class: ______________

Hoop Glider Assessment – Fractions

1. Jamal wants to make a Hoop Glider that has the large hoop as a whole strip and the small hoop as $\frac{7}{10}$ of the whole. On the blank strip below, divide it correctly and shade in how long his small strip would be.



2. Decompose 7/10 in two different ways, using words, pictures, and numbers.

3. Antonia and Megan made a new Hoop Glider. Their large strip is one whole. Their smaller strip is ⅔ of the whole. Antonia believes their smaller hoop is more than ½, and Megan believes their smaller hoop is less than ½. Who is correct in their reasoning? Draw the strips to explain your thinking.

Name: ___________________________________

Date: ____________ Class: _________________

4. How do engineers use math? Explain, in at least three sentences, some ways that engineers might use math in their jobs.

"I use math almost all the time!"
- Aidan Begg, Senior Mechanical Engineer at Lockheed Martin

Name: ______________________________

Date: __________ Class: ______________

Hoop Glider Assessment – Fractions <u>ANSWER KEY</u>

1. Jamal wants to make a Hoop Glider that has the large hoop as a whole strip and the small hoop as 7/10 of the whole. Use the blank strips below, divide it correctly and shade in how long his strip would be.

1

2. Decompose 7/10 in two different ways, using words, pictures, and numbers.

Multiple answers are acceptable.

3. 3. Antonia and Megan made a new Glider. Their large strip is one whole. Their smaller strip is ⅔ of the whole. Antonia believes their smaller hoop is more than ½, and Megan believes their smaller hoop is less than ½. Who is correct in their reasoning? Draw the strips to explain your thinking.

½	½

$\frac{1}{3}$	$\frac{1}{3}$	

$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$		

↑

$\frac{3}{6} = \frac{1}{2}$

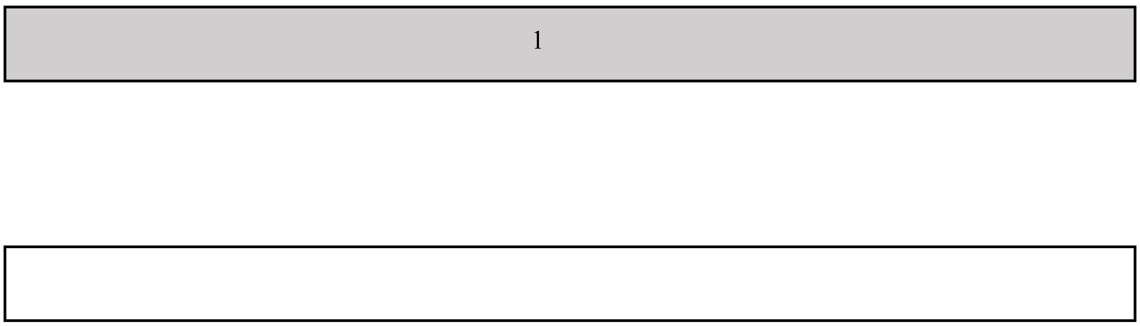
Antonia is correct, because the 2/3 is greater than 1/2; 4/6 is greater than 3/6.

Name: ___________________________________

Date: ____________ Class: _________________

Hoop Glider Assessment – Ratios and Proportions

1. Jamal wants to make a Hoop Glider that has a ratio of the large hoop to the small hoop of 7 to 10. Use the blank strip below, divide and shade it correctly to show how long his strips should be.



2. Write two additional ratios that are equivalent to the ratio 7 to 10.

3. Antonia and Megan are making a new hoop glider with the ratio of small strip to large strip of 4/6. Their large strip is already cut and is 9 inches long. How long will they need to cut their smaller strip? Solve a proportion to prove your answer.

Name: ___________________________________

Date: ____________ Class: _________________

4. How do engineers use math? Explain, in at least three sentences, some ways that engineers might use math in their jobs.

"I use math almost all the time!"
- Aidan Begg, Senior Mechanical Engineer at Lockheed Martin

Name: ______________________________

Date: __________ Class: ______________

Hoop Glider Assessment – Ratios and Proportions ANSWER KEY

1. Jamal wants to make a Hoop Glider that has a ratio of the large hoop to the small hoop of 7 to 10. Use the blank strip below, divide and shade it correctly to show how long his strips should be.

2. Write two additional ratios that are equivalent to the ratio 7 to 10.

   Answers will vary.

3. Antonia and Megan are making a new hoop glider with the ratio of small strip to large strip of 4/6. Their large strip is already cut and is 9 inches long. How long will they need to cut their smaller strip? Solve a proportion to prove your answer.

$$\frac{4}{6} = \frac{x}{9}$$

$$6x = 4(9)$$

$$6x = 36$$

$$x = 6$$

The shorter strip will need to be cut 6 inches long.