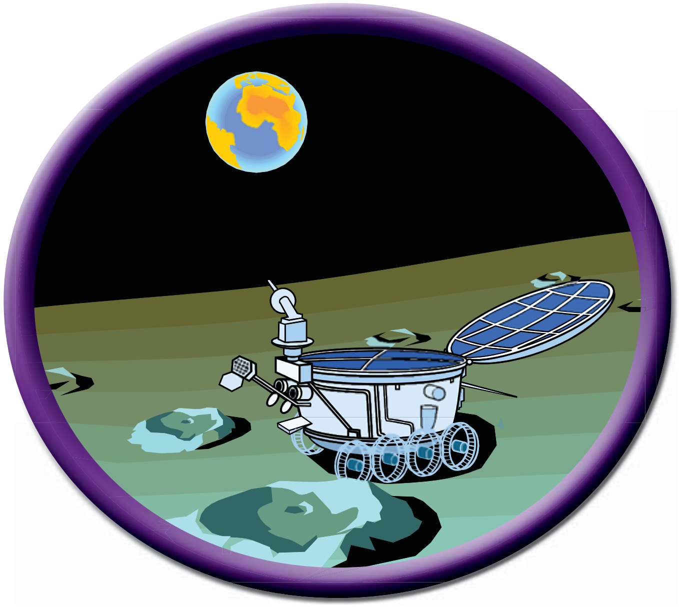


Rover Design Challenge

This lesson is included in Module 2.

LEVEL
Fifth Grade

OBJECTIVES
Students will

- Develop an understanding of the engineering practices.
- Understand a transportation problem with constraints.
- Apply appropriate measuring skills

MATERIALS AND RESOURCES

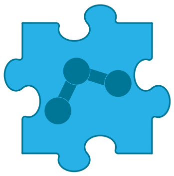
- Cardstock preprinted with centimeter squares.
- Tape
- Scissors
- Rulers (centimeters)
- Stiff material – foam board or wood – to use as ramp for testing containers

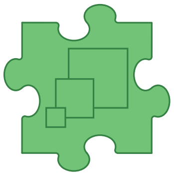
ABOUT THIS LESSON

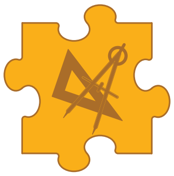
NASA has successfully used rovers to explore the surface of Mars. The rovers must be able to carry important scientific equipment without breaking or falling over. Once a volume is established it must be maintained; only the dimensions can change. Students will design and test three storage containers. Students will be challenged to create their own criteria for a successful design based on the materials available and the ramp or ramps provided for testing. A posted list of criteria developed by the students in the class will be used by the students to evaluate their design success. The Teacher will supply chassis for testing.

PRIOR LEARNING
Students are familiar with calculating volume.

SCIENTIFIC PRACTICES
The Next Generation Science Standards (NGSS) are designed to engage students in Scientific and Engineering Practices by using Crosscutting Concepts to deepen the student's understanding of Disciplinary Core Ideas. NMSI has developed icons to provide a visual reference for teachers to denote which dimensions students will explore during a given lesson


DEVELOPING AND USING MODELS


SCALE, PROPORTION, AND QUANTITY


ETS1: ENGINEERING DESIGN

STANDARDS FOR SCIENCE CONTENT

NMSI science lessons will be aligned with the Next Generation Science Standards that are currently in development. These standards are said to be developed around the anchor documents, *A Framework for K-12 Science Education*, which was produced by the National Research Council. Where applicable, the NMSI science lessons are also aligned to the Common Core Standards for Mathematical Content as well as the Common Core Literacy Standards for Science and Technical Subjects.

TARGETED STANDARDS

3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

REINFORCED/APPLIED STANDARDS

5.MD.5 Relate volume to the operations of multiplication and addition and solve real world and mathematical problems involving volume.

- **a.** Find the volume of a right rectangular prism with whole-number side lengths by packing it with unit cubes, and show that the volume is the same as would be found by multiplying the edge lengths, equivalently by multiplying the height by the area of the base. Represent threefold whole-number products as volumes, e.g., to represent the associative property of multiplication.
- **b.** Apply the formulas $V = l \times w \times h$ and $V = b \times h$ for rectangular prisms to find volumes of right rectangular prisms with whole number edge lengths in the context of solving real world and mathematical problems.
- **c.** Recognize volume as additive. Find volumes of solid figures composed of two non-overlapping right rectangular prisms by adding the volumes of the non-overlapping parts, applying this technique to solve real world problems.

COMMON CORE STATE STANDARDS FOR MATHEMATICAL PRACTICE

These standards describe a variety of instructional practices based on processes and proficiencies that are critical for mathematics instruction. NMSI incorporates these important processes and proficiencies to help students develop knowledge and understanding and to assist them in making important connections across grade levels. This lesson allows teachers to address the following Common Core State Standards for Mathematical Practice.

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

MP.5 Use appropriate tools strategically.

NMSI CONTENT PROGRESSION CHART

In the spirit of NMSI's goal to connect mathematics across grade levels, the Content Progression Chart demonstrates how specific skills build and develop from third grade through fifth grade. Each column, under a grade level or course heading, lists the concepts and skills that students in that grade should master. Each row illustrates how a specific skill is developed as students advance through their mathematics courses.

3rd Grade Skills/ Objectives	4th Grade Skills/ Objectives	5th Grade Skills/ Objectives
3.MD.5 Recognize area as an attribute of plane figures and understand concepts of area measurement. **a.** A square with side length 1 unit, called "a unit square," is said to have "one square unit" of area, and can be used to measure area. **b.** A plane figure which can be covered without gaps or overlaps by n unit squares is said to have an area of n square units.	**4.MD.3** Apply the area and perimeter formulas for rectangles in real world and mathematical problems.	**5.MD.5** Relate volume to the operations of multiplication and addition and solve real world and mathematical problems involving volume. a. Find the volume of a right rectangular prism with whole-number side lengths by packing it with unit cubes, and show that the volume is the same as would be found by multiplying the edge lengths, equivalently by multiplying the height by the area of the base. Represent threefold whole-number products as volumes, e.g., to represent the associative property of multiplication. **b.** Apply the formulas $V = l \times w \times h$ and $V = b \times h$ for rectangular prisms to find volumes of right rectangular prisms with whole number edge lengths in the context of solving real world and mathematical problems. **c.** Recognize volume as additive. Find volumes of solid figures composed of two non-overlapping right rectangular prisms by adding the volumes of the non-overlapping parts, applying this technique to solve real world problems.

TEACHER PAGES

ACCOMMODATIONS/ SCAFFOLDING SUGGESTIONS

Gifted and Talented (GT)

- Challenge students to create chassis to test rover storage containers.
- The volume units are either centimeters or inches. The rover storage containers are scale models of the real thing. Challenge students to determine actual size if one centimeter equals one meter or other scale.

English Language Learners (ELL)

- Power Point support provides visual clues to help students with their understanding of the requirements. Teacher may create a sample set of containers with the same volume to demonstrate the challenge.

Special Education (Sp. Ed.)

- Nets for rectangular prisms may be created in advance so students can cut them out and put them together to proceed directly to testing. Teacher may create a sample set of containers with the same volume to demonstrate the challenge.

THE FOLLOWING ARE FORMATIVE ASSESSMENTS:

- Plan and explain nets for different design choices
- Change dimensions of the rover carrier without changing the total volume
- Explain best design using evidence

THE FOLLOWING ARE SUMMATIVE ASSESSMENTS:

- Design documents are complete
- Test data is complete
- Students are able to compare results of test and make a recommendation based on evidence from their data
- Students correctly measure volume
- The volume of all three designs remain the same

TECHNOLOGY SUGGESTIONS

- Create your own graph paper http://incompetech.com/graphpaper/plain/

REFERENCES

- A Framework for K-12 Science Education – a free copy is available at http://www.nap.edu/catalog.php?record_id=13165
- National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* (pp. 201-214). Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
- Teach Engineering Website provides an excellent overview of the engineer design process. http://www.teachengineering.org/engrdesignprocess.php

COMMON MISCONCEPTIONS

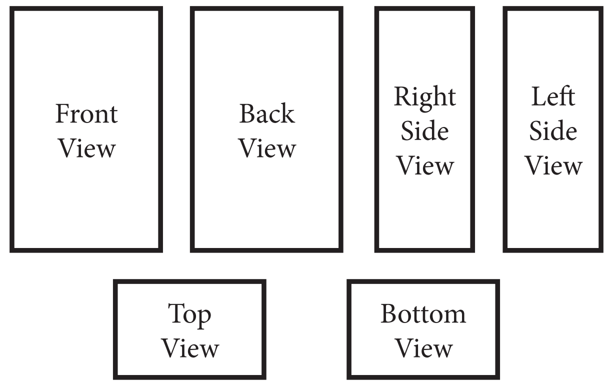
- The volume can only be made with one configuration of length, width and height.
- Speed is the most important accomplishment. The rover must slide down the ramp without tipping or rolling over.

LESSON WITH TEACHING SUGGESTIONS

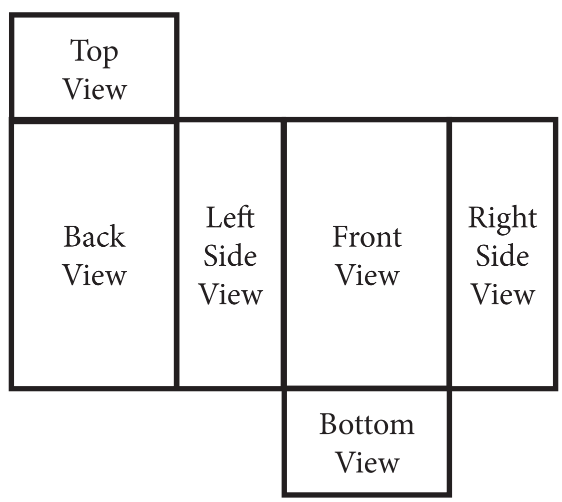
1. Engineering begins with the definition of a problem. Engage students by introducing the problem. In this case the students are presented with the problem of selecting volume for the rover storage container. Students need to design and test three rover storage containers with the same volume and different dimensions. The power point can assist you in introducing the problem.
2. Ask the students to predict how changing the dimensions of the container will affect the stability of the rover as it travels down steep hills.
3. Engineering projects are suited for small group work. Students may work in groups of two.
4. Explain to students that they will build and test three rover storage container designs. After their group has found the best design they will present the design to the rest of the class.
5. Note that this activity may be a challenge for students.

UNDERSTANDING NETS

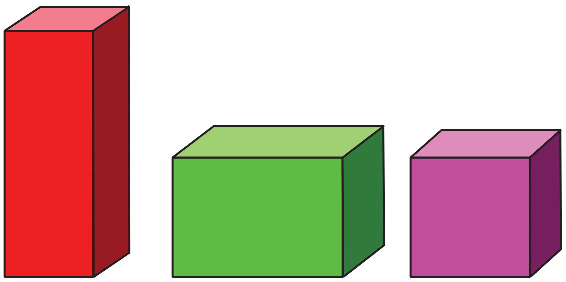
1. Prepare a set of labels with the following titles: Front View, Back View, Left Side View, Right Side View, Top View, Bottom View and Net. You will add the labels to each view of the prism as it is deconstructed.
2. Share with students that we will need to understand how rectangular prisms are constructed before we can create a net and make our own for the rover challenge. We will be reviewing nets and views before constructing our own.
3. You may use a cereal box or similar item to model the deconstruction of the rectangular prism. Be sure all sides can be removed in one piece. I tape the top back together if the box has already been opened.
4. Explain that we will deconstruct the completed rectangular prism to see how it is made. In this first step only unfold the rectangular prism. Label each view as it is unfolded. Note for students that each rectangle is also a face of the rectangular prism.



5. Next cut the box apart into individual views or faces of the rectangular prism.
6. Explain that we will layout the pieces of the box edge-to-edge like a puzzle so it can be put back together. You will be building a net of the rectangular prism you took apart in order to put it back together again. Note for the students that the top view edge and the bottom view edge cannot be placed side-by-side because there are sides between the top and the bottom faces.



7. Create a second set of labels. Apply the labels to an uncut rectangular prism. This time cut along the edges only to be able to unfold the rectangular prism. You will be showing the students a net. Nets are the two dimensional patterns that can be folded to create a three dimensional shape.
8. Challenge students to deconstruct a cereal box or other similar rectangular prism they have brought to school from home to create a net. Students should label each view or face.
9. Distribute pre-drawn nets for rectangular prisms and cubes to students. A quick internet search for rectangular prism and cube nets should give you a selection of nets to use with your students. You may also check your math textbook for examples. Have students cut out the nets and put them together. Students should label each view or face.
10. Ask students to compare the cube and rectangular prisms noting similarities and differences. Students should see that the faces of the cube are all the same and both examples have six faces.
11. Distribute Student Practice Sheet One. Students should label the faces of the rectangular prisms, cut them out and put them together.
12. Challenge students to draw the nets of the shapes. The measurements of the faces are provided. Students will draw to scale on the graph paper provided and label the faces. Students should cut out the shapes and check their work by assembling the rectangular prisms.



13. Ask students to brainstorm why the volume selected can be made into containers with three different designs. Why is the sample $64 cm^3$ and not $63 cm^3$ or $65 cm^3$? What makes this number easy to work with for creating multiple containers with the same volume? How do you know that the volume you selected will work? What math can we do to show that the selected volume will work?

RETURN TO THE PROBLEM

1. Students should be given constraints for the project. The first constraint will be the materials supplied for the building of the rover storage container. You may want to limit the size by providing students with centimeter squares graph paper printed on cardstock for instance. Another constraint requires students to change the angle of the ramp the rover storage container must travel down without tipping or rolling over. The angle will be anywhere from 35° to 75°.
2. Work with students to establish criteria for success with their rover storage containers. How will we evaluate with container is the best design. Some suggestions may include; did the vehicle with the storage container travel down the ramp without tipping over, can the container be balance easily on the chassis, will the design impede the ability of the rover to maneuver the terrain of Mars, will the design cause the rover to be too tall or too wide and so on? Create a design rubric and post in the classroom using the student generated criteria.

3. Students may use a rover chassis to transport their container. The design challenge could include the design of the rover chassis as well as the rover storage container. The chassis could simply be a small car designed to roll down a track. Students could attach the rover storage container to the car and test how the vehicle travels down the ramp. Chassis could be built from building supplies with wheels and a ramp created from foam board. Other designs may be considered as well.

THE ENGINEERING PROCESS

Note – there are several slight variations on the engineering process. This is a version designed to introduce fifth graders to the engineering process. It may be modified to fit the engineering design process used in your current curriculum or as defined by state standards.

Define the Problem

This step will be completed as a class.

1. Ask the students to restate the problem in their own words.
2. Help students define the constraints.
3. Ask students how we should determine which rover storage container design is the best.
4. Create a check list of criteria for a rover storage container. The list may include safety and speed. The check list could be created or modified by the teacher if students are not ready for this task.

Plan

1. Working with their partner students should draw a design for the rover storage container.
2. Use the Rover Storage Container Design handout.
3. The design should clearly identify the dimensions and volume calculation of the rover storage container.

Make

1. Students should conference with the teacher to explain their design and verify that the constraints are met.
2. Grant permission to build and test once the design is approved.

Test

1. Students should compare their rover storage container design to the check list created when the problem was defined.
2. Students should answer the questions on the Rover Storage Container Design handout.

Improve

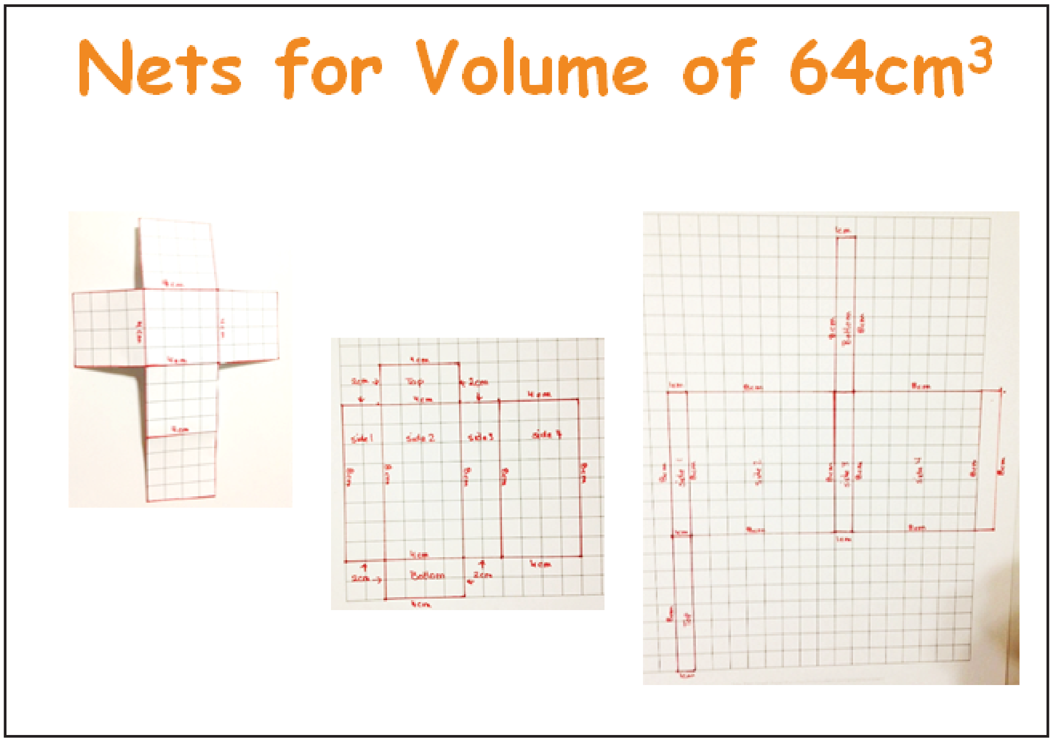
1. Students should plan two more designs for comparison to attempt to improve upon the original design.

Share

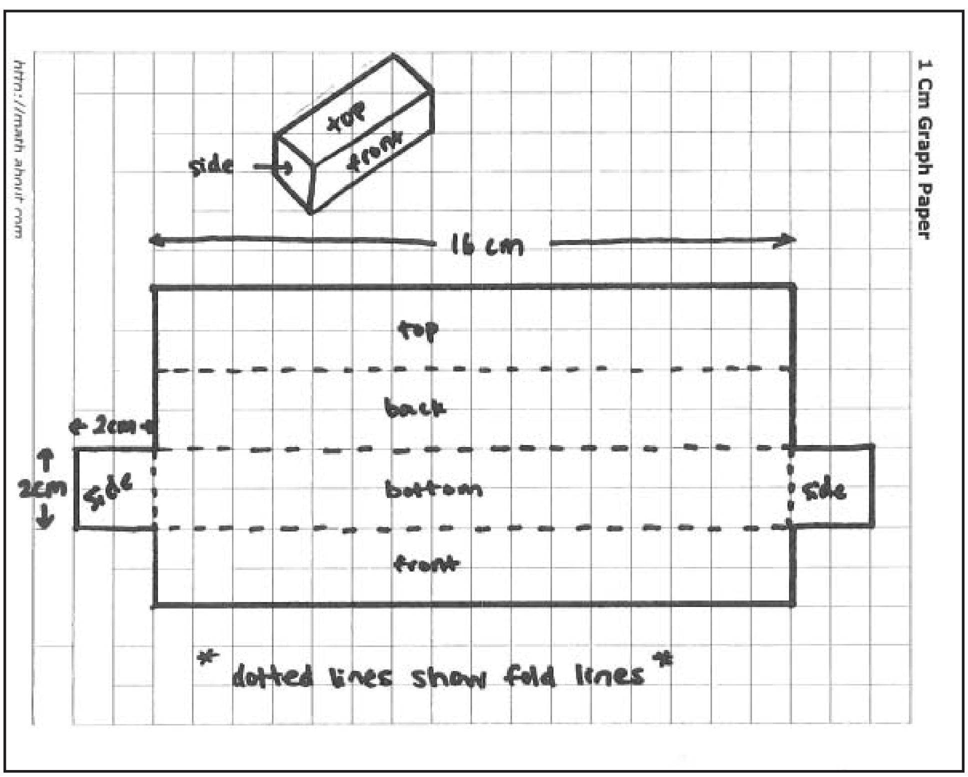
1. Students should prepare to share their design with the rest of the class.
2. Using the data they collected about size safety and speed they should explain which of their designs was the best. Students are developing skills to make decisions based on evidence.

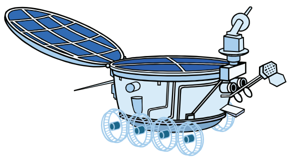
ANSWERS

Answers for this lesson will vary. To obtain the maximum benefit of the lesson, ask students to go beyond the expected responses. Students should be able to explain why the selected design choice for the carrier is the best. Student designs will be varied. This project helps students understand that there may be more than one correct answer to a problem. Student answers should show a good understanding of measurement.



Share an example with students.

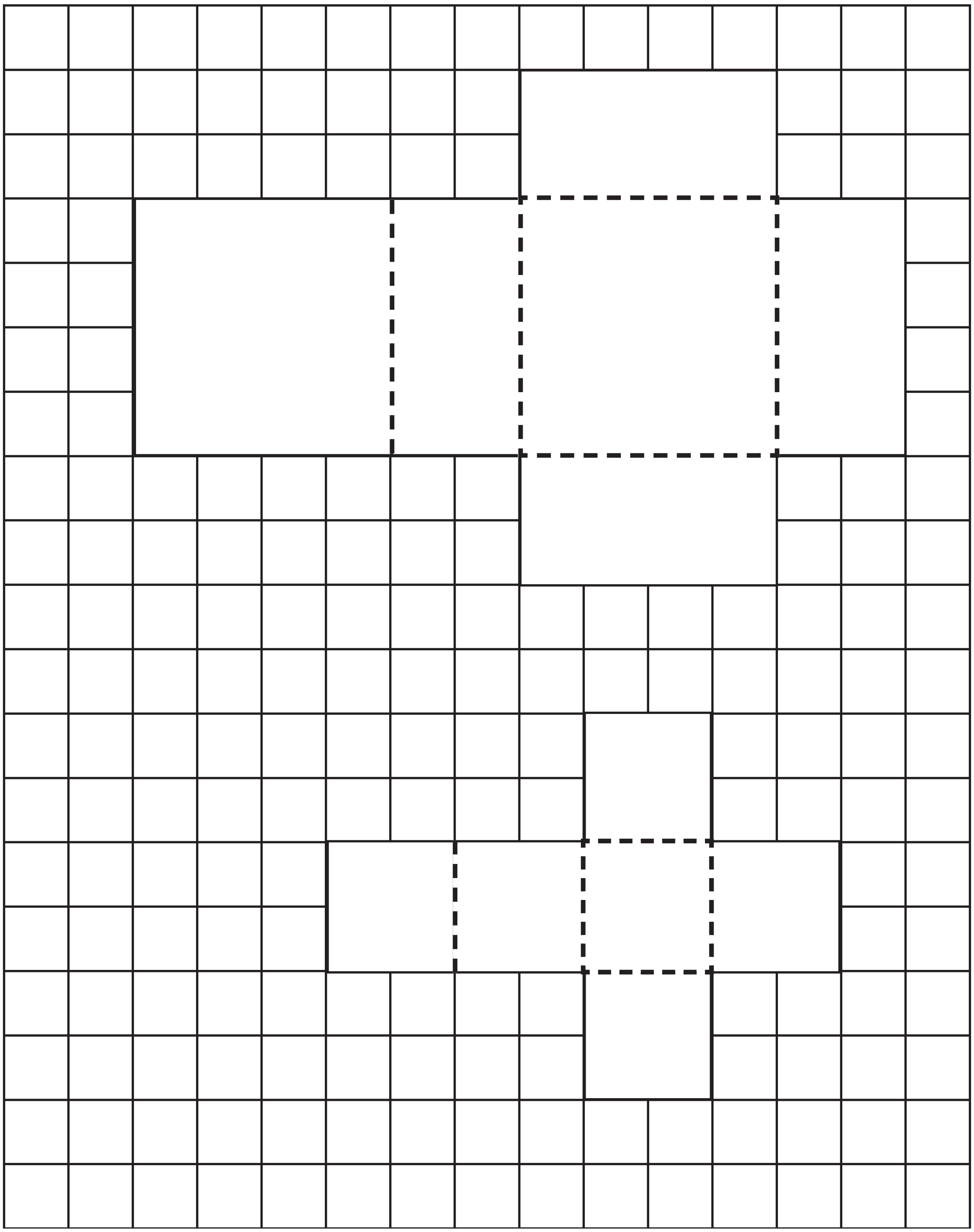




Engineering Challenge

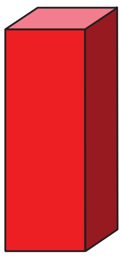
STUDENT PRACTICE 1

Label the faces of the rectangular prisms: Top, Bottom, Right Side, Left Side, Front and Back. Cut out and assemble the nets of the rectangular prisms.

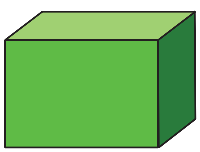


STUDENT PRACTICE 2

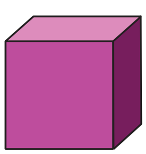
Draw the nets of the rectangular prisms below using the measurements notes. Cut out and assemble your drawings top check your work.



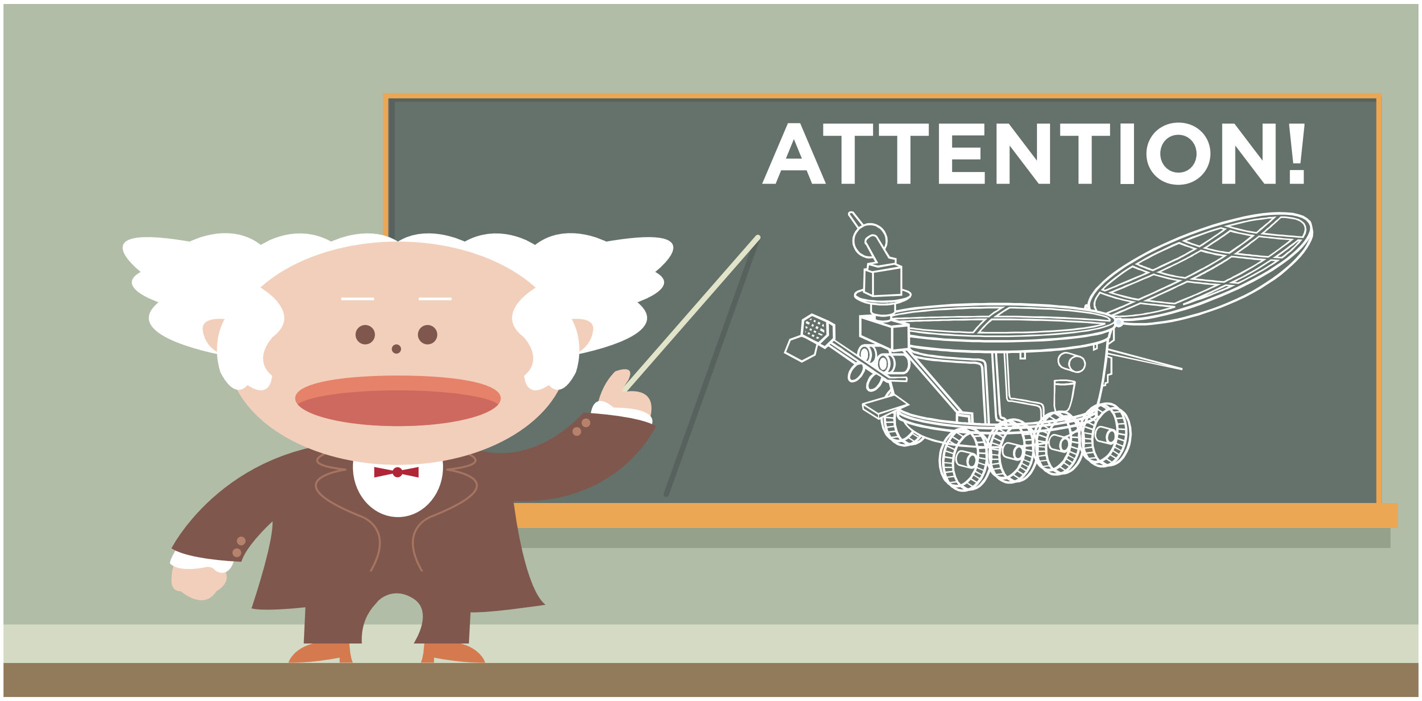
Top and Bottom Faces
2cm × 2cm
Front, Back and Side Faces
2cm × 4cm



Top and Bottom Faces
2cm × 4cm
Left and Right Facess
2cm × 3cm
Front and Back Faces
3cm × 4cm



All Face
2cm × 2cm



CALLING ALL ENGINEERS!!

NASA needs workable rover containers that will successfully simulate the transportation of scientific equipment down steep terrain.

As the designers, your job is to

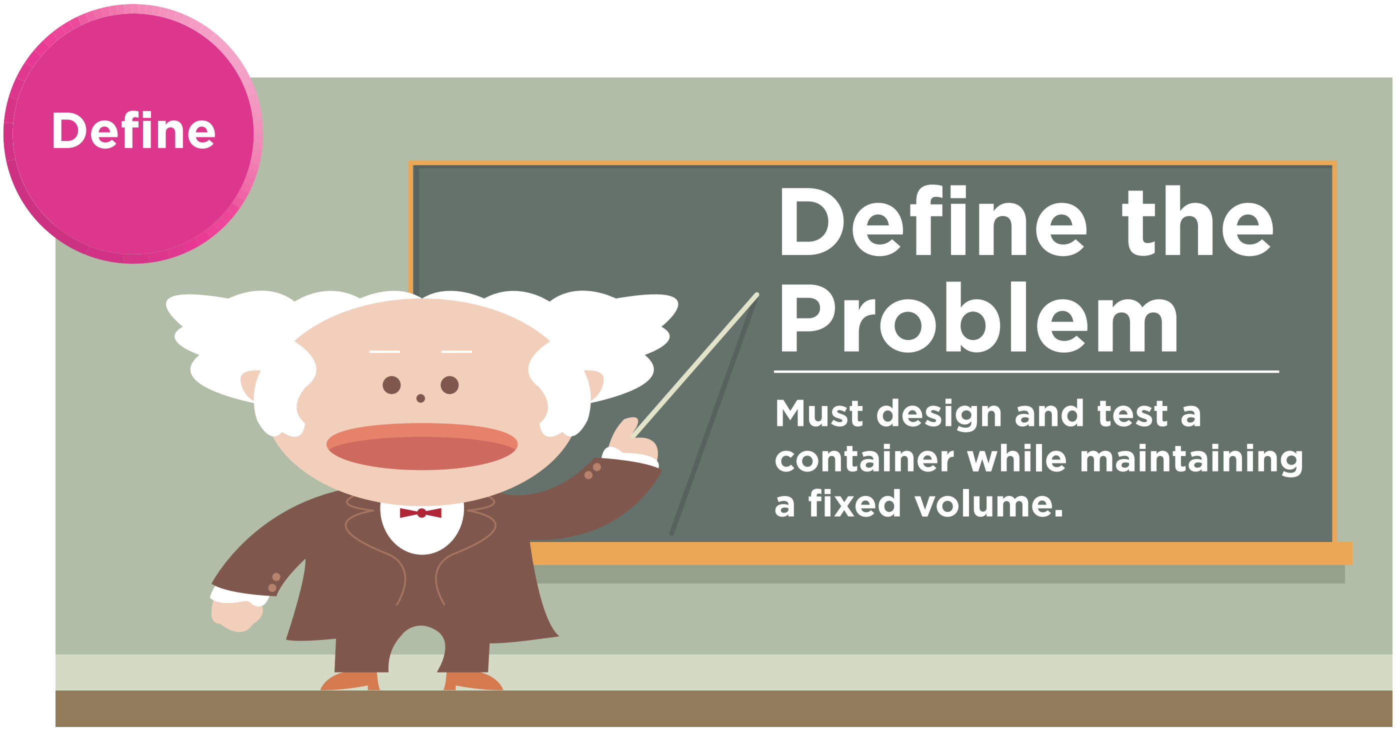
- discuss and decide what criteria can make the containers for the rovers stable during movement while traveling down a ramp.
- use the given rubric to design and build 3 containers with different dimensions that are equal in volume.
- share your group's most successful design and explain why you think it could be a successful container.

Creativity is encouraged!

Engineers, begin discussing and decide what criteria can make the containers for the rovers "successful."

The containers' overall stability during movement or how fast the container moves down a ramp could be factors (among others) that you and your classmates decide to judge.

Your group's overall performance will be graded on how well your containers meet the criteria or factors you and your group create. Follow the rubric you will be given to guide your decisions when building the containers.

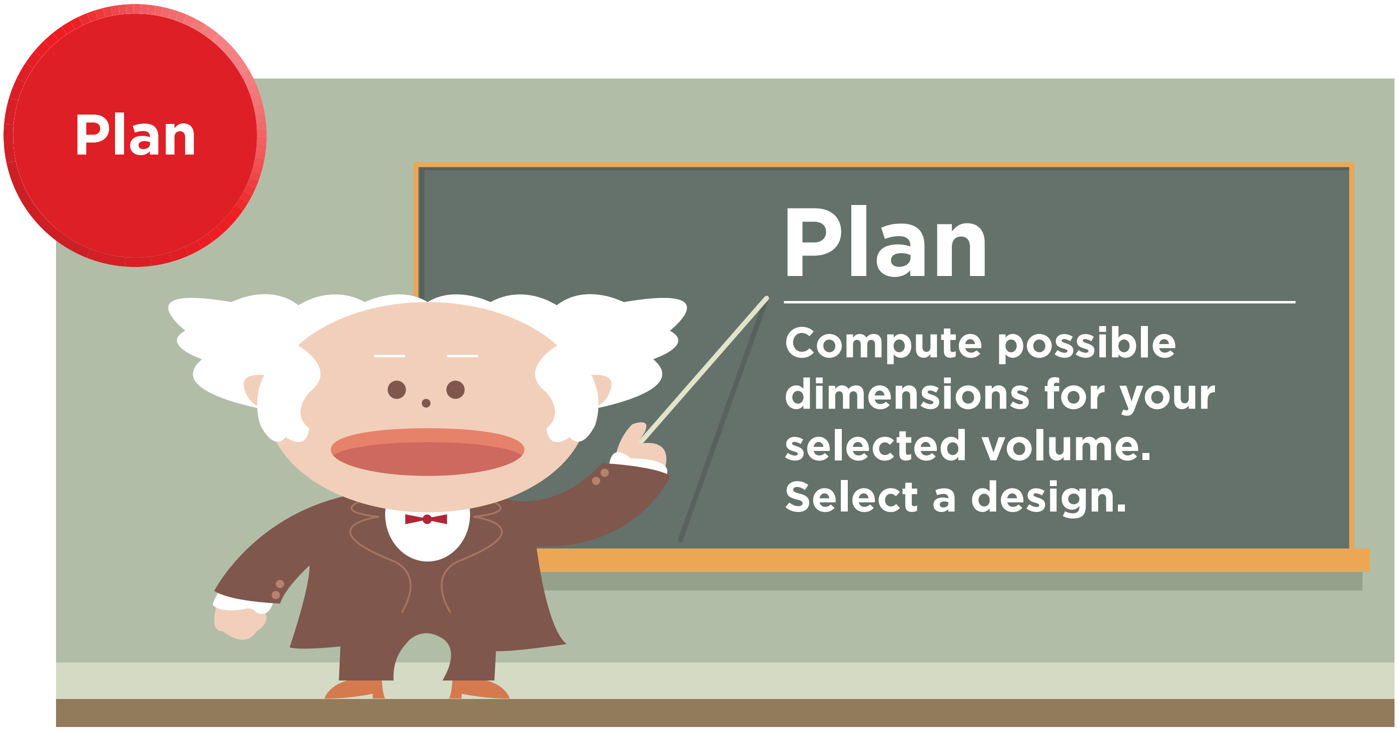


The objective of this activity is to design, build, and test three (3) containers of the same volume moving down a ramp.

- Come up with 3 different designs for containers that all have volumes of 64 cubic centimeters.
- Compare these designs, and pick the design that you believe will be most successful.
- You should be ready to answer questions about why you chose that design and what benefits your design has over others.

Like in any design scenario, your team must make sure that all constraints are met; otherwise the objective will be compromised. Some constraints are listed below:

- The containers must all have the same volume in cubic centimeters.
- You may only use the materials supplied.
- The container must be able to travel successfully down the ramp with a varying angle between 35° to 75°.
- The container must not tip or roll over while traveling down the ramp.
- The base of the container (the part of the container that touches the chassis) must not be wider than the ramp itself.



- Select a volume for your container designs.
- Select length, width and height for your container design.
- Draw a picture of your design. Draw a net of the container design.
- Present your design document to recieve approval to build.

NAME(S): ____

Planning Guide
Rover Storage Container Design 1

Dimensions and sketch.
Create net of rectangular prism on graph paper.

Height of container: ____

Width of container: ____

Length of container: ____

Volume of container: ____

Approved for building or testing: ______________________________

NAME(S): ______________________________

Planning Guide
Rover Storage Container Design 2

Dimensions and sketch.
Create net of rectangular prism on graph paper.

Height of container: ______________________________

Width of container: ______________________________

Length of container: ______________________________

Volume of container: ______________________________

Approved for building or testing: ______________________________

NAME(S): ____________________________________

Planning Guide
Rover Storage Container Design 3

Dimensions and sketch.
Create net of rectangular prism on graph paper.

Height of container: ____________________________________

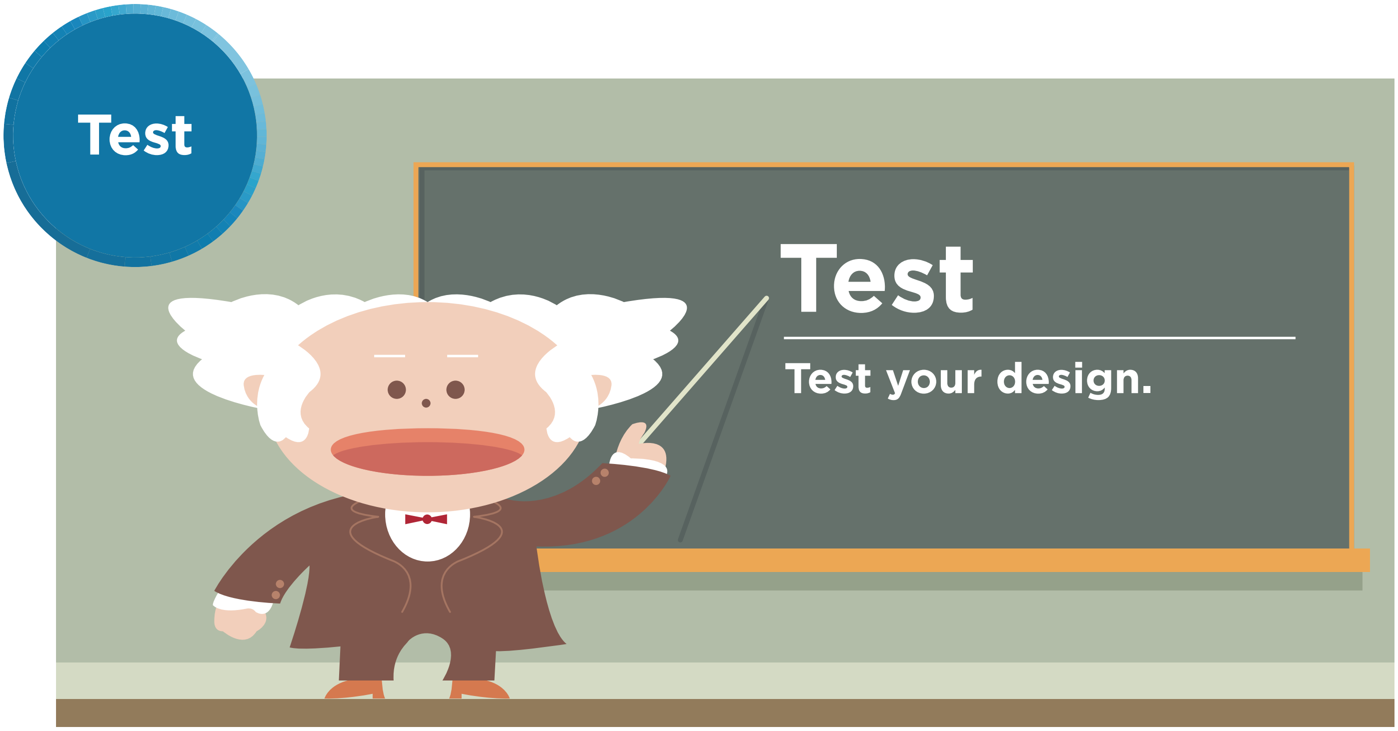
Width of container: ____________________________________

Length of container: ____________________________________

Volume of container: ____________________________________

Approved for building or testing: ____________________________________

Build you design using the materials listed on your planning guide.



Pick roles for you and your partner:

- Partner will start the container down the ramp.
- One partner will report on the movement of the rover. Was it stable? Will the cargo be safe?
- Test your design three times.

NAME(S): ___________________________________

ROVER STORAGE CONTAINER DESIGN 1 TEST RESULTS

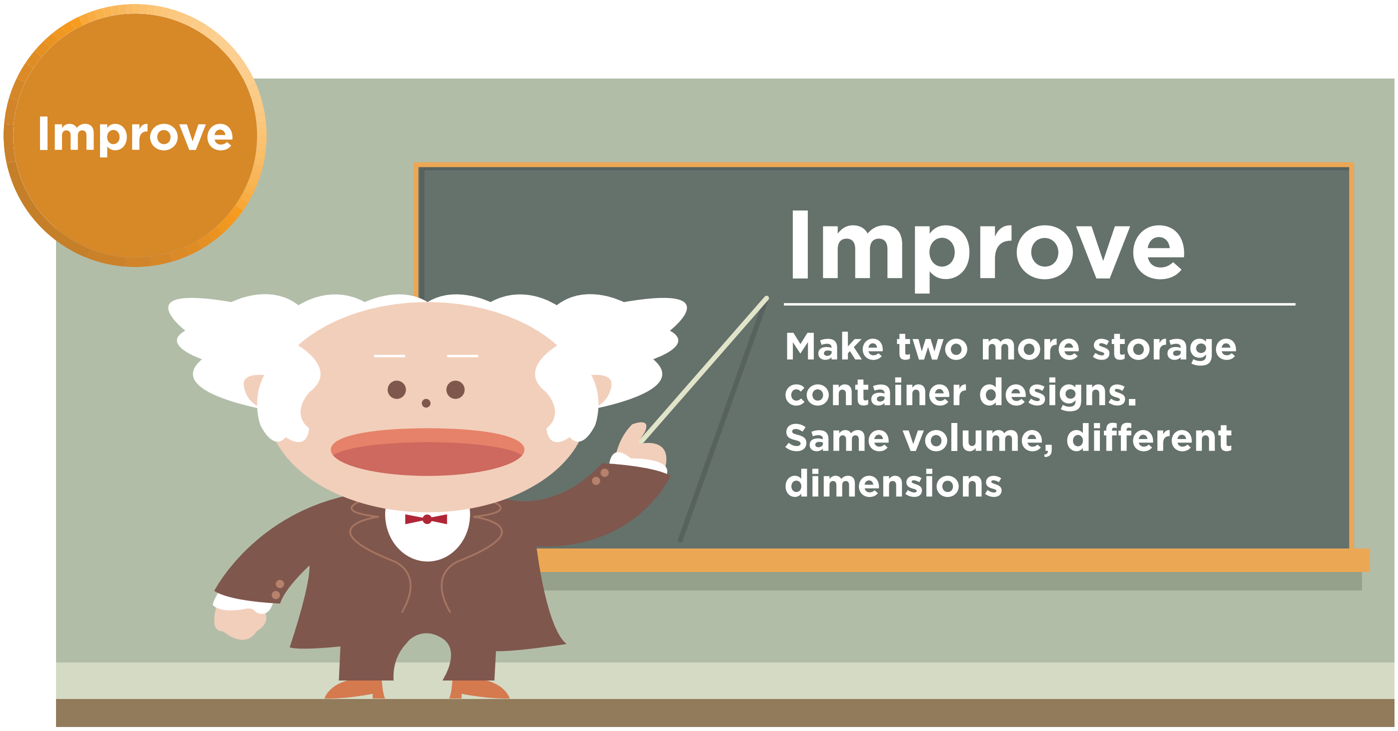
TRIAL	TIME	NOTES:
1		
2		
3		

ROVER STORAGE CONTAINER DESIGN 2 TEST RESULTS

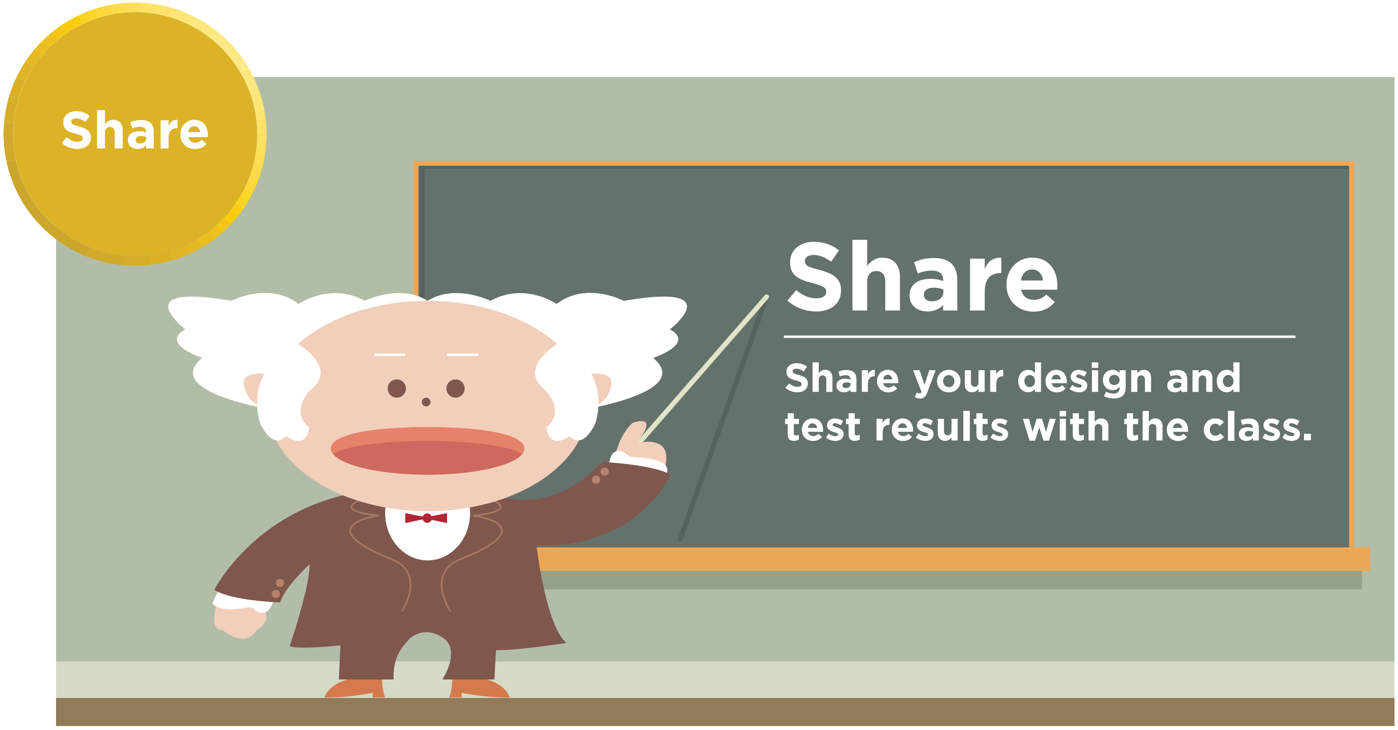
TRIAL	TIME	NOTES:
1		
2		
3		

ROVER STORAGE CONTAINER DESIGN 3 TEST RESULTS

TRIAL	TIME	NOTES:
1		
2		
3		



- Work with your partner to decide what changes to the dimensions can be made to improve your rover cargo container.
- Plan another design. Complete the planning document and present it for approval to build.
- Make, test and improve three times.



- Work with your partner to decide the best design based on your results.
- Complete the sharing guide.
- Present your suggested design to the class.

NAME(S): ______________________________

Sharing Guide

Our best design drawing:

Height of container: ______________________________

Width of container: ______________________________

Length of container: ______________________________

Volume of container: ______________________________

Best Time: ____________

Explain why you selected this design for the Rover.

____

____

____

____

____

____

NAME:______________________ **ENGINEERING DESIGN RUBRIC**

Student will be able to	Expert	Proficient	Emerging	Novice
Plan Complete the planning guide	Student completes planning and explains design choices without assistance.	Student completes planning guide and offers some explanations for design choice with minimal with guidance and support.	Student completes planning guide and explanations for choices with some guidance and support from teacher or peers.	Student completes planning guide with guidance and support from teacher.
Make Make a simple design	Student makes and tests a well-developed design without assistance.	Student makes and tests a simple design with minimal with guidance and support.	Student builds and tests a simple design with some guidance and support from teacher or peers.	Student builds and tests a simple design with guidance and support from teacher.
Test Test, record times & observe	Student evaluates test results without assistance.	Student evaluates test results using the data collected with minimal with guidance and support.	Student evaluates test results with some guidance and support from teacher or peers.	Student evaluates test results with guidance and support from teacher.
Improve Improve rover container design	Student changes dimensions while maintaining volume without assistance.	Student changes dimensions while maintaining volume with minimal with guidance and support.	Student changes dimensions while maintaining volume with some guidance and support from teacher or peers.	Student changes dimensions while maintaining volume with guidance and support from teacher.
Share Share best design	Students can share best design and explain selection using class generated criteria without assistance.	Students can share best design and explain selection using class generated criteria with minimal with guidance and support.	Students can share best design and explain selection using class generated criteria with some guidance and support from teacher or peers.	Students can share best design and explain selection using class generated criteria with guidance and support from teacher.
 ß Apply Math Skills	Student measures volume of design without assistance.	Student measures volume of design with minimal with guidance and support.	Student measures volume of design with some guidance and support from teacher or peers.	Student measures volume of design with guidance and support from teacher.

Engineering Design Process