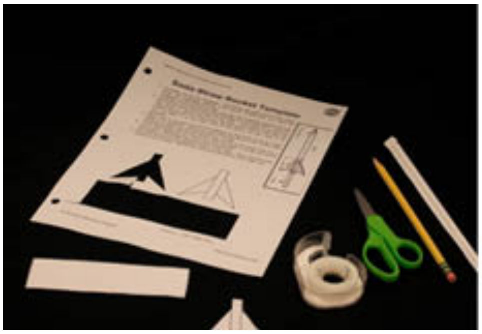
Lesson: Soda Straw Rockets

Grades: K-8 **Prep Time:** ~45 Minutes **Lesson Time:** ~90 Minutes



WHAT STUDENTS DO: Test a rocket model and predict its motion.

Curiosity about what lies beyond our home planet led to the first rocket launches from Earth and to many exploration missions since. Using simple materials (soda straws and paper), students will experience the processes involved in engineering a rocket. Conducting engineering tests, students will have the opportunity to answer a research question by collecting and analyzing data related to finding out the best nose cone length and predicting the motion of their model rockets. In this collection, this lesson builds on the concept of using models encountered in Lessons 1-3, and introduces the concepts of prediction and hypothesis.

NRC CORE & COMPONENT QUESTIONS	INSTRUCTIONAL GOAL
HOW DO ENGINEERS SOLVE PROBLEMS? *NRC Core Question: ETS1: Engineering Design*	*Students will be able*
What Is a Design for? What are the criteria and constraints of a successful solution? *NRC ETS1.A: Defining & Delimiting an Engineering Problem*	**IO1: to generate** explanations based on evidence from tests of model
HOW CAN ONE EXPLAIN AND PREDICT INTERACTIONS BETWEEN OBJECTS AND WITHIN SYSTEMS OF OBJECTS? *NRC Core Question: PS2: Motion and Stability*	
How can one predict an object's continued motion, changes in motion, or stability? *NRC Component Question: PS2.A: Forces and Motion*	

On behalf of NASA's Mars Exploration Program, this lesson was prepared by Arizona State University's Mars Education Program, under contract to NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology.

1.0 About This Activity

This activity is part of the Imagine Mars Project, co-sponsored by NASA and the National Endowment for the Arts (NEA). The Imagine Mars Project is a hands-on, STEM-based project that asks students to work with NASA scientists and engineers to imagine and to design a community on Mars using science and technology, then express their ideas through the arts and humanities, integrating 21st Century skills. The Imagine Mars Project enables students to explore their own community and decide which arts-related, scientific, technological, and cultural elements will be important on Mars. Then, they develop their concepts relating to a future Mars community from an interdisciplinary perspective of the arts, sciences, and technology. imaginemars.jpl.nasa.gov

The Imagine Mars lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (see *Section 4* and *Teacher Guide)* at the end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures. Construction of rubrics also draws upon Lanz's (2004) guidance, designed to measure science achievement.

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Imagine Mars instructional series. The 5E stages can be cyclical and iterative.

2.0 Materials

Required Materials

Please supply:

- 30 Sharpened Pencils (1 per person)
- 15 Scotch Tape Rolls – 1/4” tape if possible (2 per group)
- 30 Individually Wrapped Drinking Straws (1 per person)
- 15 Meter Sticks or Tape Measures (2 per group)
- LCD projector and computer with internet access to find pictures or video of rockets on the following site: http://www.nasa.gov/centers/kennedy/launchingrockets/archives/elv_archive-index.html.

Materials Provided

Please Print:

From Student Guide:

(A) Soda Straw Rocket Template – 1 per student
(B) Soda Straw Rocket Data Log – 1 per pair of students
(C) Soda Straw Rocket Data Analysis Graph – 1 per pair of students
(D) Soda Straw Rocket Analysis – 1 per student

Optional Materials

From Teacher Guide:

(E) “Soda Straw Rocket” Assessment Rubrics
(F) Alignment of Instructional Objective(s) and Learning Outcome(s) with Knowledge and Cognitive Process Types

3.0 Vocabulary

Analyze consider data and results to look for patterns and to compare possible solutions

Data facts, statistics, or information

Empirical Evidence knowledge gained through direct or indirect observation

Engineering a field in which humans solve problems that arise from a human need or desire by relying on their knowledge of science, technology, engineering design, and mathematics (derived from NRC Framework, 2012).

Explanations logical descriptions applying scientific information

Graph	a diagram representing the relationship between facts or statistics
Hypothesis	a suggested explanation that predicts a particular outcome based on a model or theory, to be shown true or false
Inquiry	a method of learning scientists use, which includes observing, **questioning**, examining what's already known, planning investigations, using tools to gather, analyze, and interpret data, proposing **hypotheses** and predicting results, and communicating findings (derived from NSES, 1996)
Mission	an operation designed to carry out the goals of the space program
Models	a simulation helps explain natural and man-made systems and shows possible flaws
Prediction	the use of knowledge to identify and explain observations or changes in advance (NSES, 1996)
Questions	scientists asks questions that can be answered using **empirical evidence**
Rocketry	a branch of science that deals with rockets and rocket propulsion

4.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Instructional objectives, standards, and learning outcomes are aligned with the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which serves as a basis for upcoming "Next-generation Science Standards." Current National Science Education Standards (NSES) and other relevant standards are listed for now, but will be updated when the new standards are available.

The following chart provides details on alignment among the core and component NRC questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and education standards.

- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.

- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see Teacher Guide at the end of this lesson).

Quick View of Standards Alignment:

The Teacher Guide at the end of this lesson provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:

HOW DO ENGINEERS SOLVE PROBLEMS?
NRC Core Question: ETS1: Engineering Design
What Is a Design for? What are the criteria and constraints of a successful solution?
NRC Component Question ETS1.A: Defining & Delimiting an Engineering Problem

HOW CAN ONE EXPLAIN AND PREDICT INTERACTIONS BETWEEN OBJECTS AND WITHIN SYSTEMS OF OBJECTS?
NRC Core Question: PS2: Motion and Stability
How can one predict an object's continued motion, changes in motion, or stability?
NRC Component Question: PS2.A: Forces and Motion

Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO1: **IO1: to generate** explanations based on evidence from tests of model	**LO1a.** **to construct** a model **LO1b.** **to hypothesize** how the model will behave (i.e., given different nose cone lengths) **L01c:** **to test** the model	**NSES: UNIFYING CONCEPTS & PROCESSES:** **K-12: Evidence, models, and explanations** **NSES (A): SCIENCE AS INQUIRY** **Abilities necessary to do scientific inquiry** **Grades K-4, 5-8:** A3 **NSES (E): SCIENCE & TECHNOLOGY** **Evaluate Completed Technological Design or Products** **Grades K-4, 5-8:** E1d	***Rubrics in Teacher Guide***

This activity also aligns with:

NSES (B): PHYSICAL SCIENCE

Grades 5-8: (B) Properties of Objects & Materials
Position & Motion of Objects

NRC SCIENCE & ENGINEERING PRACTICES

2) Developing and using models
3) Planning and carrying out investigations
4) Analyzing & interpreting data
5) Using mathematical and computational thinking
6) Constructing explanations and designing solutions

NRC SCIENCE & ENGINEERING CROSSCUTTING CONCEPTS

2) Cause and effect
4) Systems and system models

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS (NCTM)

- Algebra
- Measurement
- Data Analysis and Probability

21ST CENTURY SKILLS

- Creativity and Innovation
- Critical Thinking and Problem Solving
- Communication
- Collaboration
- Flexibility and Adaptability
- Initiative and Self-Direction
- Productivity and Accountability

5.0 Procedure

PREPARATION (~15 minutes)

- Set up authorized target for rockets (globe, ball, a round circle on an easel).
  - Access pictures of rockets on the internet: http://www.nasa.gov/centers/kennedy/launchingrockets/archives/elv_archive-index.html

- Print:

  - Student Sheets (A-D) – 1 per student

Teacher Tips

1. If possible, use ¼" tape for taping the rockets. The smaller size works more easily and can be applied without over-taping areas.
2. Do not distribute the straws until all the students are finished with their rocket and you are ready to have the class begin the launches. Use wrapped straws for sanitary purposes.
3. Have the students line up in a horizontal line to launch the rockets. Depending on the number of students, you may have to have sequential launches take place. An outside venue, cafeteria or gym would work great, as you could spread the students out and allow them to make their measurements easily. Make sure you let them know that no unauthorized launches can be done! They must launch when given permission.
4. Having a launch countdown as a group is always fun! (e.g., 10,9,8,7…)
5. Always provide an authorized target (globe, ball, etc. for students to direct their aim).
6. If students take their rockets home, please advise that no rockets may be launched on the bus!

7. If you use Soda Straw Rockets for other venues (school space nights, open house, etc.), make sure you have a target for the students. Provide a small ziplock bag in which students can place their rockets and ask them not to launch in other places.
8. To save time, it is very helpful if you have extra rocket pieces already cut for students who struggle with cutting.

STEP 1: ENGAGE (~20 minutes)

Research common rocket features

A. Blast off! Getting off Earth and toward a solar system destination is exciting. How do we know we can get where we want to go? Engineering design is important to helping us reach our goals. For this engagement, you will be modeling steps in the inquiry process for your students, from observation and questioning to testing and acquiring results, as well as engineering design. As students get older, they will be able to complete these steps on their own.

B. Show images of rockets. For initial engagement, you can also begin with "Mars in a Minute: How do we launch to Mars?" as a cartoon teaser for more in-depth content. Research video and images of rockets that NASA sends into space. (http://www.nasa.gov/centers/kennedy/launchingrockets/archives/elv_archive-index.html). Ask students what they may notice about the rockets and the launches. Do they have something in common?

C. Guide the students to look directly at the nose cone of the rocket. Are there any differences? What would happen if a different cone were used? Maybe if it was shorter, longer, or didn't have one?

D. What do the students predict would happen to the distance a rocket will travel if changes were made to the cone?

E. Let's investigate that question! Have students fill out their hypothesis on *(D) Soda Straw Rocket Analysis (Question 1).*

Curiosity Connection Tip: For making a connection to NASA's Mars Rover "Curiosity," please show your students additional video and slideshow resources at:

http://mars.jpl.nasa.gov/participate/marsforeducators/soi/

STEP 2: EXPLORE (~30 minutes)

Design and implement rocket investigation

A. Give students the *(A) Soda-Straw Tem*plates and direct them to write their names on the fins of the rockets. Review the directions on how to construct their rocket.

Teacher Tip: Have students work in pairs to construct the rocket tubes. One student can hold the tube tight on the pencil and the other student can apply the tape to the paper tube. Students build the rocket on the pencil. Tell them not to remove it from the pencil until you are ready to distribute the straws.

B. Students can be organized into groups of 4 so that each of the students within the group can build a rocket with a different length of nose cone.

C. Students should select a control for this investigation. Discuss that the purpose of a control is to have something to which you can compare the results. This control should be similar to what you are testing, but something that will be unaffected by the things you are changing. For this investigation, construct one control rocket that has almost no nose cone at all. Just tape the end of the paper tube closed.

D. Students will launch each rocket one at a time and record the distance it traveled (in centimeters) on the *(B) Data Log*.

E. Students may wish to write in any observations they want to remember as they perform their investigations (things such as direction for example).

F. Students should do five trials of the investigation and record the results on their *(B) Data Log*.

G. Students will then graph their data on the *(C) Data Analysis Sheet* in order to draw a conclusion as to which nose cone length produced the best rocket.

STEP 3: EXPLAIN (~10 minutes)

Drawing conclusions from data and evidence

A. Students will write a conclusion for their results. The conclusion should discuss the nose cone lengths used and what they saw happen in their investigation. You may even push the students a little further by asking them to explain why this is the result. What is the reason that a longer cone will have a longer or shorter distance?

STEP 4: ELABORATE (~10 minutes)

Consider other possible variables

A. Give students the opportunity to evaluate other possible variables that could affect the flight pattern of a rocket. They may come up with examples such as: angle of launch, # of fins, length of the tube, weighted with paper clips, etc. This exercise helps to build your students to participation in a full inquiry model. If time permits, give them the opportunity to explore some of these different variables and report results out to the class.

STEP 5: EVALUATE (~20 minutes)

Reflect on findings from rocket testing

A. Ask students to complete the *(D) Soda Straw Rocket Analysis Worksheets* so that they can draw conclusions based on evidence from their tests.

6.0 Extensions

In Step 4: Elaborate, investigate the purpose of nose cones (they hold the payload of rockets) and some of the changes that have to be made to accommodate launching larger payloads into space (e.g., larger rockets, strap-on boosters to add more thrust, etc.).

7.0 Evaluation/Assessment

In the Teacher Guide, use the *(E) "Soda Straw Rocket" Rubric* as a formative assessment that aligns with the NRC Framework, National Science Education Standards, and the Instructional objective(s) and learning outcomes in this lesson.

8.0 References

Anderson, L.W., & Krathwohl (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York: Longman.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications.* Colorado Springs: BSCS.

Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom.* Washington, DC: The National Academies Press.

Lantz, H.B. (2004). *Rubrics for Assessing Student Achievement in Science Grades K-12.* Thousand Oaks: Corwin Press.

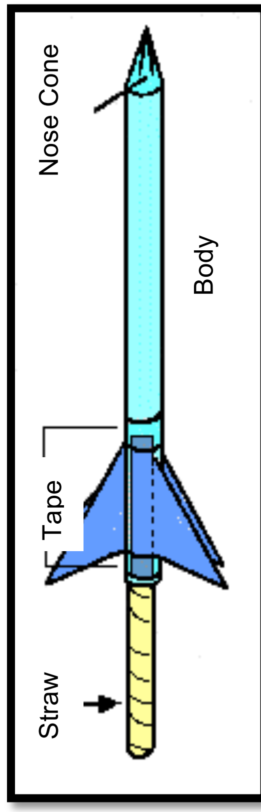
Miller, Linn, & Gronlund. (2009). *Measurement and assessment in teaching*. Upper Saddle River, NJ: Pearson.

National Academies Press. (1996, January 1). *National science education standards*. Retrieved February 7, 2011 from http://www.nap.edu/catalog.php?record_id=4962

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* 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.

The Partnership for 21st Century Skills (2011). *A framework for 21st century learning.* Retrieved March 15, 2012 from http://www.p21.org/

(A) Student Worksheet. Soda-straw rocket template (1 of 2)



1. **1.** Carefully cut out the rectangle. It will be the body tube of the rocket. Wrap the rectangle around a #2 pencil, lengthwise, and tape the rectangle so that if forms a tube.

2. **2.** Carefully cut out the two fin units and align the rectangle between the two fins with the end of your body tube. Tape it to the body tube. Tape the tube about ¼" above the end of the tube. That helps to prevent the taping of the fin to the pencil. Do the same thing for the other fin unit, but tape it on the other side of the pencil, so you have a "fin sandwich."

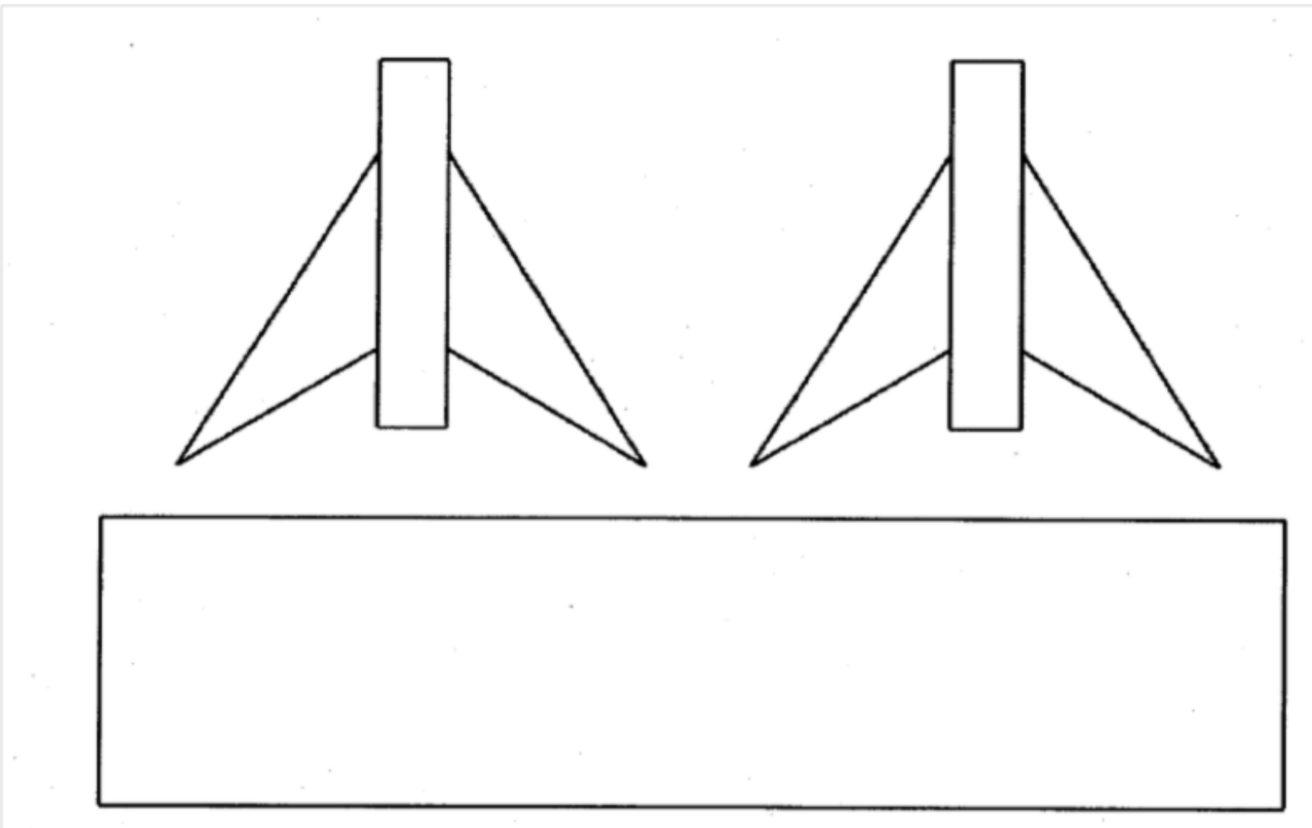
3. **3.** Bend one fin on each fin unit 90 degrees so that each fin is at a right angle to its neighbor. When you look along the back of the rocket (near the pencil eraser), the fins should form a "+" mark.

4. **4.** At the sharpened end of your pencil, twist the top of the body tube into a nose cone. Measure your nose cone from the base to its tip and record the length on your (B) Data Log and on the rocket itself.

5. **5.** Remove the pencil and replace it with a soda straw. Blow into the straw to launch your rocket. Remember launch safety! Never point your rocket at a person. Your goal is to get to your target destination! Record the distance it travels on your (B) Data Log.

(A) Student Worksheet. Soda-straw rocket template (2 of 2)

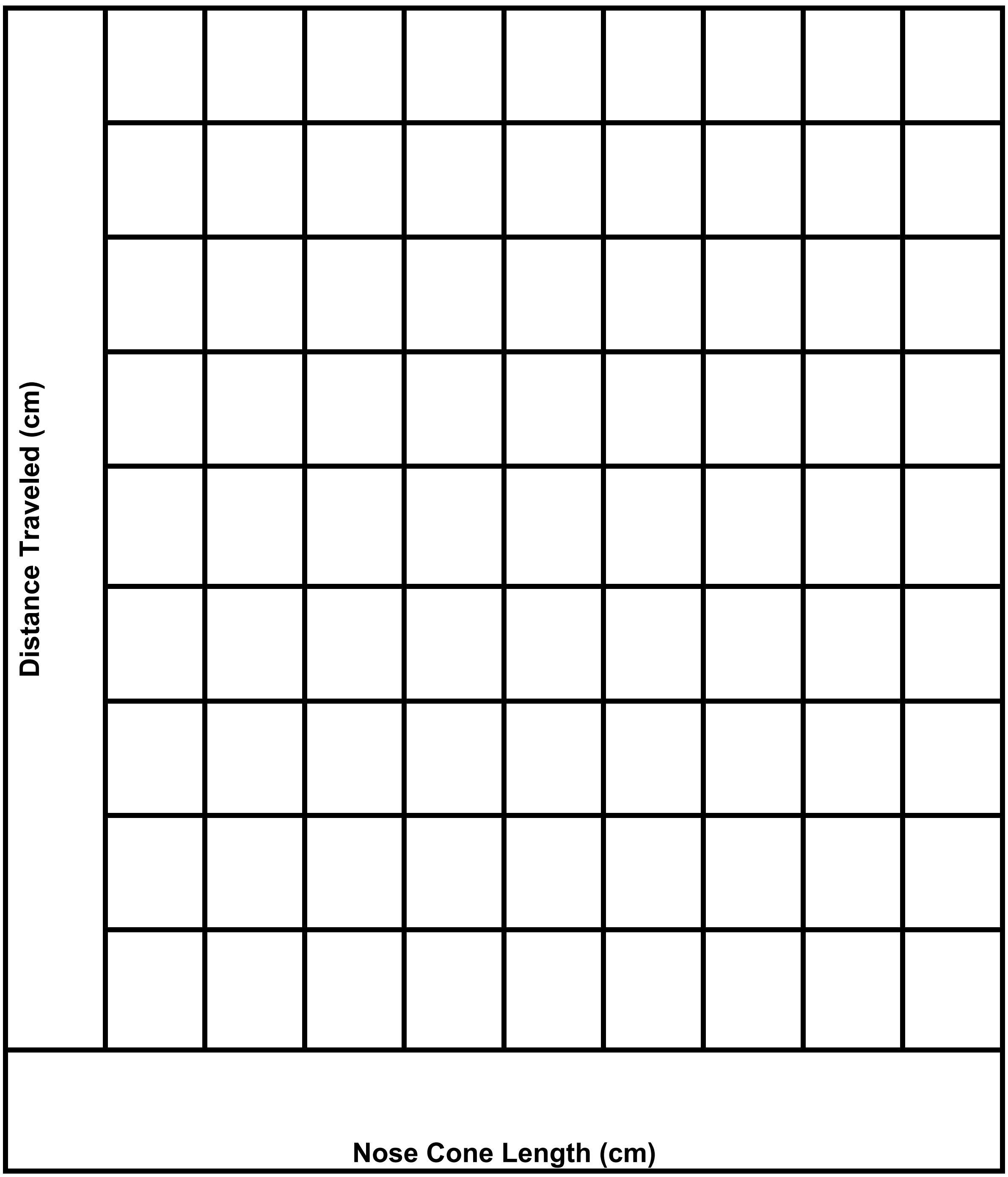
Soda Straw Rocket Template – Cut these three pieces out carefully.



(B) Student Worksheet. Soda-straw rocket data log

Length of Nose Cone	Trial #1	Trial #2	Trial #3	Trial #4	Trial #5	Notes
Control						
Distance Traveled (in cm)						

(C) Student Worksheet. Soda-straw data analysis graph



(D) Student Worksheet. Soda-straw Rocket Analysis (1 of 2)

Your Research Question:
How will changes to the rockets' nose cone length affect the distance the rocket will travel?

1. Your Prediction (Your Hypothesis):

____

____

____

2. Your Conclusion:

A. What Nose Cone Lengths did your team use? _____, _____, _____, _____.

B. What happened to the Distance Traveled when you had a longer Nose Cone?

____

____

____

C. What happened to the Distance Traveled when you had a shorter Nose Cone?

____

____

____

D. Why do you think these results happened?

____

____

____

(D) Student Worksheet. Soda-straw Rocket Analysis (2 of 2)

E. Did you have any problems during the investigation that might have changed the Distance Traveled?

____

____

____

F. Was your prediction supported? __________

G. If yes, what evidence do you have your prediction was supported? If no, why do you think it wasn't supported?

____

____

____

H. Other than nose cone length, give 3 examples of variables that might be changing the Distance Traveled.

1. ________________________

2. ________________________

3. ________________________

I. Pick one of the examples and give a hypothesis (a suggested explanation that predicts a particular outcome, based on a model or theory) as to why this variable might change the Distance Traveled of the rocket.

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(E) Teacher Handout. Soda Straw Rocket Rubric

You will know the level to which your students have achieved the **Learning Outcomes**, and thus the **Instructional Objective(s)**, by using the suggested **Rubrics** below.

Instructional Objective 1: To generate explanations based on evidence from tests of model

Related Standard(s) (will be replaced when new NRC Framework-based science standards are released):

National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES

Grades K-12: Evidence, models, and explanations
Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as “hypothesis,” “model,” “law,” “principle,” “theory,” and “paradigm” are used to describe various types of scientific explanations.

As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

National Science Education Standards (NSES)
(A) Science as Inquiry: Abilities necessary to do scientific inquiry

Grades K-4: (A3) In the earliest years, investigations are largely based on systematic observations. As students develop, they may design and conduct simple experiments to answer questions. The idea of a fair test is possible for many students to consider by fourth grade. Simple skills, such as how to observe, measure, cut, connect, switch, turn on and off, pour, hold, tie, and hook. Beginning with simple instruments, students can use rulers to measure the length, height, and depth of objects and materials; thermometers to measure temperature; watches to measure time; beam balances and spring scales to measure weight and force; magnifiers to observe objects and organisms; and microscopes to observe the finer details of plants, animals, rocks, and other materials. Children also develop skills in the use of computers and calculators for conducting investigations. This aspect of the standard emphasizes the students' thinking as they use data to formulate explanations. What constitutes evidence and judge the merits or strength of the data and information that will be used to make explanations. After students propose an explanation, they will appeal to the knowledge and evidence they obtained to support their explanations. Students should check their explanations against scientific knowledge, experiences, and observations of others. The abilities to communicate, critique, and analyze their work and the work of other students. This communication might be spoken or drawn as well as written.

Grades 5-8:
(A3) Design & Conduct a Scientific Investigation. Students should develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables. They should also develop the ability to clarify their ideas that are influencing and guiding the inquiry, and to understand how those ideas compare with current scientific knowledge. Students can learn to formulate questions, design investigations, execute investigations, interpret data, use evidence to generate explanations, propose alternative explanations, and critique explanations and procedures.

(A5) Develop descriptions, explanations, predictions, and models using evidence. Students should base their explanation on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description—providing causes for effects and establishing relationships based on evidence and logical argument. This standard requires a subject matter knowledge base so the students can effectively conduct investigations, because developing explanations establishes connections between the content of science and the contexts within which students develop new knowledge.

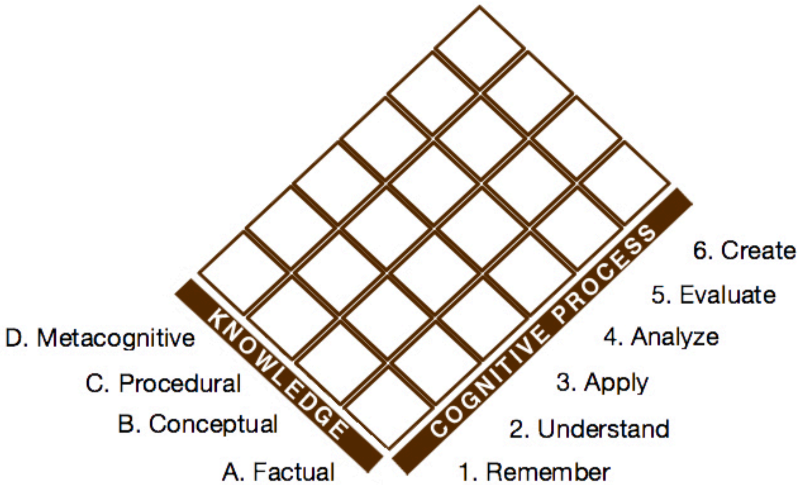
National Science Education Standards (NSES)
(E) Science and Technology: Abilities of Technological Design
Evaluate a Product or Design. Students should evaluate their own results or solutions to problems, as well as those of other children, by considering how well a product or design met the challenge to solve a problem. When possible, students should use measurements and include constraints and other criteria in their evaluations. They should modify designs based on the results of evaluations. (Grades K-4: E1d)

Evaluate a Product or Design. Students should use criteria relevant to the original purpose or need, consider a variety of factors that might affect acceptability and suitability for intended users or beneficiaries, and develop measures of quality with respect to such criteria and factors; they should also suggest improvements and, for their own products, try proposed modifications. (Grades 5-8: E1d)

(E) Teacher Handout. Soda Straw Rocket Rubric (Continued)

	Expert	Proficient	Intermediate	Beginner
LO1a: Construct a model	Model is constructed carefully and according to instructions. Measurements of nose cone are highly accurate and precise.	Model is constructed carefully and according to instructions. Measurements are accurate and precise.	Model is mostly constructed according to instructions. Measurements are accurate.	Model is not completely constructed according to instructions. Measurements are not completely accurate.
LO1b: Hypothesize how model will behave	Hypotheses are based on sound reasoning and evidence.	Hypotheses are mostly based on sound reasoning and evidence.	Hypotheses are somewhat based on sound reasoning and evidence.	Hypotheses are not based on sound reasoning and evidence.
LO1c: Test the model	Observations and data are highly accurate, systematic, and complete.	Observations and data are mostly accurate, systematic, and complete.	Observations and data are somewhat accurate, systematic, and complete.	Observations and data are not very accurate, systematic, or complete.

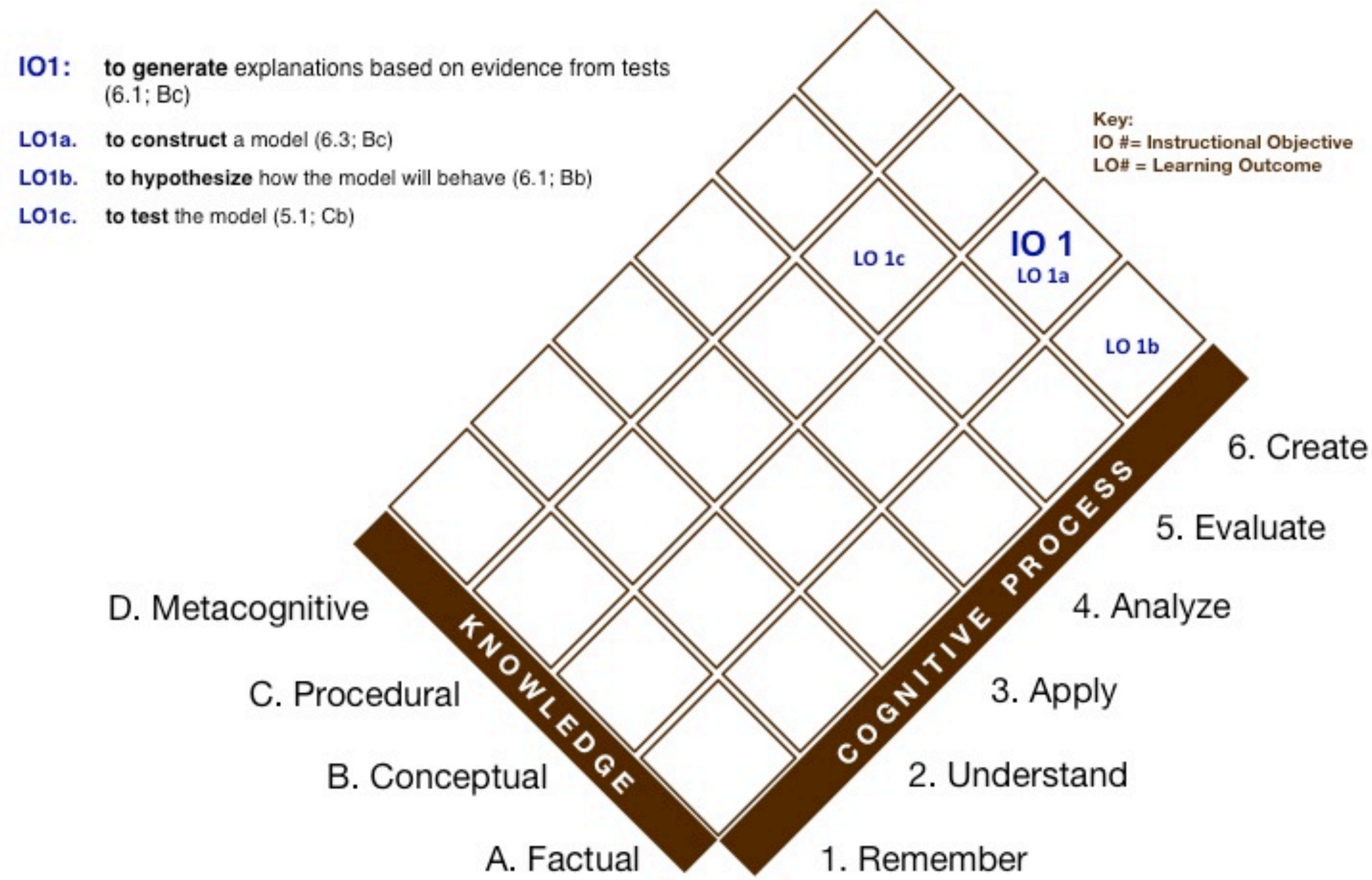
(F) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (1 of 3)



This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s). Activity procedures and assessments are designed to support the target knowledge/cognitive process.

Knowledge	Cognitive Process
A. Factual **Aa:** Knowledge of Terminology **Ab:** Knowledge of Specific Details & Elements **B. Conceptual** **Ba:** Knowledge of classifications and categories **Bb:** Knowledge of principles and generalizations **Bc:** Knowledge of theories, models, and structures **C. Procedural** **Ca:** Knowledge of subject-specific skills and algorithms **Cb:** Knowledge of subject-specific techniques and methods **Cc:** Knowledge of criteria for determining when to use appropriate procedures **D. Metacognitive** **Da:** Strategic Knowledge **Db:** Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge **Dc:** Self-knowledge	**1. Remember** **1.1** Recognizing (Identifying) **1.2** Recalling (Retrieving) **2. Understand** **2.1** Interpreting (Clarifying, Paraphrasing, Representing, Translating) **2.2** Exemplifying (Illustrating, Instantiating) **2.3** Classifying (Categorizing, Subsuming) **2.4** Summarizing (Abstracting, Generalizing) **2.5** Inferring (Concluding, Extrapolating, Interpolating, Predicting) **2.6** Comparing (Contrasting, Mapping, Matching **2.7** Explaining (Constructing models) **3. Apply** **3.1** Executing (Carrying out) **3.2** Implementing (Using) **4. Analyze** **4.1** Differentiating (Discriminating, distinguishing, focusing, selecting) **4.2** Organizing (Finding coherence, integrating, outlining, parsing, structuring) **4.3** Attributing (Deconstructing) **5. Evaluate** **5.1** Checking (Coordinating, Detecting, Monitoring, Testing) **5.2** Critiquing (Judging) **6. Create** **6.1** Generating (Hypothesizing) **6.2** Planning (Designing) **6.3** Producing (Constructing)

(F) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)



(F) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (3 of 3)

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Below are the knowledge and cognitive process types students are intended to acquire per the instructional objective(s) and learning outcomes written for this lesson. The specific, scaffolded 5E steps in this lesson (see 5.0 Procedures) and the formative assessments (worksheets in the Student Guide and rubrics in the Teacher Guide) are written to support those objective(s) and learning outcomes. Refer to (F, 1 of 3) for the full list of categories in the taxonomy from which the following were selected. The prior page (F, 2 of 3) provides a visual description of the placement of learning outcomes that enable the overall instructional objective(s) to be met.

At the end of the lesson, students will be able

IO1: to generate explanations based on evidence from tests of model
- **6.1:** to generate
- **Bc:** knowledge of theories, models, and structures

To meet that instructional objective, students will demonstrate the abilities:

LO1a: to construct a model
- 6.3: to construct
- Bc: knowledge of theories, models, and structures

LO1b: to hypothesize model's behavior
- 6.1: to hypothesize
- Bb: knowledge of principles and generalizations

LO1c: to test the model
- 5.1: to test
- Cb: knowledge of subject-specific techniques and methods