OFFICE OF ADULT AND CONTINUING EDUCATION
475 Nostrand Avenue Brooklyn, NY 11216
P: (718) 638-2635 F: (718) 623-2080
Rose-Marie Mills, Superintendent

# Building Essential Test Readiness Skills in Science for the TASC
# Part 2: Inquiry and the Nature of Science

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**Tom Trocco, Director of Program Support for OACE, ttrocco@schools.nyc.gov**

## Agenda

Learning Objectives: You will be able to:

- Better understand the Nature of Scientific Inquiry
- Use strategies and resources to engage students in science content
- Better understand the TASC Science assessment, and the content and process skills students need to master

Introductions
Objectives
Instructional Updates: Anecdotes since April

**The 5E's Instructional Model**

**Inquiry and the Nature of Science**
- Engage: TAPPS Activity
- Explore: Number Cube

*Break*
- Explain: Nature of Scientific Inquiry
- Elaborate: Text-Rendering
- Evaluate: Name Cube

**The Structure of the TASC**
- TASC Test Design

*Lunch*

**Earth and Space Sciences**
The Dark Side of the Moon
How Much Do You Weigh in Space?
*Break*

**Life Science**
Surface Area-to-Volume Ratio in a Cell

Final Reflections & Evaluations

# Jigsaw Description

*Adapted from the work of Spencer Kagan, Resources for Teachers, San Juan Capistrano, CA.*

The purpose of Jigsaw is shared learning. Members of a group become "experts" in a particular area of a mutual pursuit and share their learning/ research with the other group members. It is also used when a lot of learning needs to happen in a short time. Chapters of books can be split up, various approaches to the same outcome can be researched, different experiments with the same materials can be conducted, different viewpoints on the same issue can be studied, and the results shared. This is effective for students or adults. There are several ways this can happen:

**Within Team Jigsaw**
Each member of a team/group works independently to master a portion of a topic or skill. When each team member has completed the work as planned, they gather at an agreed upon time to share the new knowledge. Often there is some kind of synthesis of the shared knowledge. *Example: There are four protocols for observing in a classroom. Each person in a group of four reads one of the observation protocols and presents that approach to the other team members, with guiding questions to assist the shared learning, such as "What kind of feedback is generated by this protocol?" "What kind of observation is most appropriate for this protocol?" "What is the value of this protocol in terms of student learning; teacher practice?" The group compares and contrasts the four protocols.*

**Team Jigsaw**
Each team becomes an "expert" on one topic or skill. Team members spread out to share their new knowledge with the rest of the teams. Team #1 spreads out and sends a member to each of the other teams to share, then Team #2 does the same. There's a bit of math to do here as there have to be enough "experts" to share with all the other teams, or teams have to be combined to share "experts." Two teams can research the same topic and check with one another for completeness and agreement before they "consult" with the other teams - this provides some checks and balances. Synthesis can be done as a whole group or in teams. *Example: There are four protocols for observing in a classroom. The room is divided into 4 teams of 3 people, (or 6 people). Each team studies one protocol, talking together and planning the best way to present the protocol to the other teams, using the guiding questions. Each team takes turns sending its "experts" out to the other teams (alone or as a pair) to share the protocol they have studied. A whole group synthesis that compares the four approaches.*

**Expert Group Jigsaw**
Each member of a team takes on a portion/aspect of a topic or skill. More than one member of the team will take on the same portion/aspect if there are more group members than portions/ aspects. The team splits up and everyone goes to an "expert" group of all the people from all the teams taking on the same portion/ aspect. The "expert" group masters the topic/skill or does the research necessary. The "expert" group plans a way to present their learning in the best possible way and practices the presentation if necessary. The "experts" all return to their teams where they make presentations to their team members. Synthesis is done in the teams. *Example: There are four protocols for observing in a classroom. Each team assigns its members one of the four protocols. The team members break up and go with the appropriate "expert" group to study the protocol, discuss it together for understanding, using the guiding questions. They plan a presentation. The "experts" return to their team and each protocol is presented in turn. The protocols are compared in the teams.*

# Jigsaw Reading: The 5 E's Instructional Model

**Reading #1: ENGAGE**

**A Five-Stage Instructional Model**

In 1985 BSCS developed a constructivist instructional model organized around five words beginning with the letter *E*: Engage, Explore, Explain, Elaborate, and Evaluate.

The focus of the 5 E's is on a structured common learning experience presented to cooperative-learning teams in five linked stages.

Students use their experiences to construct and develop knowledge and meaning as they progress through each of the stages.

This model has two fundamental characteristics in common with most real-world learning: It involves learning by doing, and it asks learners to collaborate with peers and experts in meeting their responsibilities.

The beginning of each discrete instructional segment—whether it's a project, an experiment, or a lesson—starts with an Engage activity.

**The Goal of the Engage Activity Is to Do One or More of the Following:**

- activate students' imaginations
- create interest in the lesson/project that follows
- provoke thinking around a specific concept or question
- generate questions, experiences, ideas for discussion and analysis
- build a pool of information that can be synthesized
- establish a baseline of understanding regarding a concept, skill, or process
- uncover students' misconceptions regarding a topic or concept
- provide a common starting point to the instructional unit

**What Does a Good Engage Activity Look Like?**

Engage activities are introductory. Some can be relatively brief, like a do now or a mini-lesson, that launches into the Explore lesson. Or the Engage activity may take up the whole period.

Engage activities should be well structured to ensure successful student participation and interest. They can focus on the topic, the concept, the skills, or the anticipated product of the upcoming instructional unit.

**Possible Engage Activities Include:**

- brainstorming of ideas, questions, explanations, or experiences
- observing and describing an object, substance, artifact
- listing or classifying items;
- taking a survey
- responding to a reading, song, image, performance that captures a concept or provokes some student questions

**An Example of an Engage Activity**

If you were doing a life cycle unit in science you might present each table with mealworms (darkling beetles) in a small box with some items of food. Students would then record observations regarding the mealworms (physical descriptions, behavioral descriptions, etc.) to develop their observational skills.

The mealworms would provide the interest and motivation. The Engage activity could end with a sharing of ideas for learning new information regarding the organisms, which would lead to exploring ideas about possible experiments.

What matters is that they always have a clear intent, succeed in capturing students' interest, bring students' knowledge and conceptions to the instructional table, and make a clear transition to the next of the 5 E's: Explore.

# Jigsaw Reading: The 5 E's Instructional Model

**Reading #2: EXPLORE**

**A Five-Stage Instructional Model**

In 1985 BSCS developed a constructivist instructional model organized around five words beginning with the letter *E*: Engage, Explore, Explain, Elaborate, and Evaluate.

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This model has two fundamental characteristics in common with most real-world learning: It involves learning by doing, and it asks learners to collaborate with peers.

The Explore stage picks up where the Engage activity left off. It might be a whole-group sharing of information/responses that were individually, partner, or team developed during the Engage; or an entirely new experience.

Essential to a successful Explore lesson is providing students with a common, somewhat open-ended investigation.

**A Successful Explore Activity Allows Students to:**

- experiment with materials or ideas
- share their unique responses to their common experience
- document their experiments, observations, investigations, methods, concerns, successes and failures
- express the fruits of their explorations in a variety of ways

**What Does a Good Explore Activity Look Like?**

Explore activities are the entire or main part of the class period in which they are presented. They may even extend to two or more class periods, depending on the grade level or complexity of the project or activity. It is essential that students have sufficient time to meaningfully pursue their explorations.

Explores are NOT paint-by-number activities that take students down a predetermined path. Instead, they frame the exploration so that everyone has a clear and common understanding of the goal or purpose. This common understanding, however, cannot restrict the freedom or remove the responsibility of students to exercise their creativity, imaginative thinking, and emerging communication skills. Students need to play with resources, problems, and solutions in a way that makes them successful learners.

**Possible Explore activities include:**

- developing hypotheses and the means to test them
- conducting beginning experiments
- identifying and planning the elements of a presentation or performance
- modeling
- trying different tools to familiarize students with their operation and utility
- improvisational role playing;
- outlining a problem and its solution
- designing a product
- categorizing
- testing previously proposed hypotheses

**Trial and Error Is Important**

Faith in the value and necessity of trial and error as an effective learning tool is implicit in each activity planned for an Explore lesson. If your Engage activity uncovered significant misconceptions involving the basic concepts about to be studied, your exploration might test those misconceptions.

A good Explore activity is a meaningful common experience for all learners. The paths they take in pursuit of their goal should build a deep understanding of the challenge and a rich variety of experiences for students to share, compare, and evaluate.

# Jigsaw Reading: The 5 E's Instructional Model

**Reading #3: EXPLAIN**

## A Five-Stage Instructional Model

In 1985 BSCS developed a constructivist instructional model organized around five words beginning with the letter *E*: Engage, Explore, Explain, Elaborate, and Evaluate.

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Students use their experiences to construct and develop knowledge and meaning as they progress through each of the stages.

This model has two fundamental characteristics in common with most real-world learning: It involves learning by doing, and it asks learners to collaborate with peers.

The middle stage of the 5 E's is the Explain lesson. It uses the information and experiences from the previous stages to organize thoughts and understandings and to make connections to the instructional goals of the project or unit. Technical vocabulary, definitions, rules and principles, formulas, and additional content information, are generally introduced here. Information is introduced or connected with previous experiences through a variety of forms.

Explain activities might occupy full class periods or part of one, depending on the format of the explanation and the processing of information.

## During a Successful Explain Lesson, Students:

- describe what they've learned and identify remaining questions or problems
- listen and record new vocabulary in their journals
- read and discuss new information regarding the concepts, ideas, and problems under investigation
- compare experiential understandings to new information
- identify and test principles, rules, and formulas
- share with their partner, team, or the whole class ideas and explanations
- review, rethink, and revise hypotheses, predictions, arguments, conclusions

## What Does a Good Explain Activity Look Like?

A successful Explain lesson involves direct instruction of students by the teacher or peers and/or self-reflection by the student. It may come in the form of brief lecture, a guided discussion, group analysis of data, or a demonstration of a successful experiment

An Explain lesson should make sense of and build on students' work in the Explore; it should not undermine that work by presenting a canned explanation or text that ignores or pays only superficial attention to students' explorations.

## Possible Explain Activities Include:

- group share and analysis of exploration results
- teacher synthesis of student questions and redirection to new resources
- jigsaw reading of new information relevant to investigation
- independent or partner reading and discussion
- teacher instruction
- simulations or recreations
- viewing and analysis of video of related investigation

## Information That Connects

Successful Explain activities refine, refocus, and reinforce students' work, linking it to the specific content and concept goals of the instructional unit in a way that validates the process of investigation and builds students' confidence in their abilities to experiment, question, hypothesize, and make sense of their learning. They present students with new information to describe, explain, understand, revise, or extend their work. They pave the way for the Elaborate lesson to come.

# Jigsaw Reading: The 5 E's Instructional Model

**Reading #4: ELABORATE**

## A Five-Stage Instructional Model

In 1985 BSCS developed a constructivist instructional model organized around five words beginning with the letter *E*: Engage, Explore, Explain, Elaborate, and Evaluate.

The focus of the 5 E's is on a structured common learning experience presented to cooperative-learning teams in five linked stages.

Students use their experiences to construct and develop knowledge and meaning as they progress through each of the stages.

This model has two fundamental characteristics in common with most real-world learning: It involves learning by doing, and it asks learners to collaborate with peers and experts in meeting their responsibilities.

Elaborate is an application and extension stage, which may involve one or more lessons. It puts into practice (or puts to the test) the learning that is the product of the Explain stage. Students may, for example, conduct redesigned experiments or use what they've learned about experiments to respond to a new object, organism, or concept with scientific analysis and a new set of experiment. Lessons in the Elaborate phase may extend over several class periods or more.

## During a Successful Elaborate, Students:

- actively put new understandings into practice
- demonstrate understanding of technical vocabulary, principles, and rules related to instructional unit goals
- generate, evaluate, and draw fresh conclusions about new data
- present conclusions with supportive evidence
- solve new problems, test new cases, try new experiments

## What Does a Good Elaborate Activity Look Like?

A successful Elaborate activity takes what students have learned so far and asks them to apply it freshly to a new situation or to revisit a situation where things didn't go according to plan and need the new understandings that grew out of the Explain to work. The difference between the Explore and the Elaborate is that the former is more open-ended and less technical.

By the Elaborate lesson, students are more focused and more connected to the instructional goals, its content, concepts, and language, than they were previously. They are also more independent in their approach to the content, posing and answering their own questions, identifying and resolving their own obstacles and glitches. Otherwise, the two look alike, particularly in two important respects: Students are working in pairs or teams on projects and activities; and they're getting their hands dirty with the real work of social studies and science: researching, experimenting, recording, revising, clarifying, analyzing.

**Possible Elaborate activities include:**

- creating and presenting new models for data gathering, organization and analysis
- designing and producing presentation documents, including maps, time lines, and graphs
- transferring information from one form or genre to another
- creating a museum exhibit

Some student work completed during the Evaluate stage can, indeed *should*, yield products for assessment. However, final assessment, both teacher and student self-assessment, occurs during the next stage, Evaluate, when products are shared.

# Jigsaw Reading: The 5 E's Instructional Model

## Reading #5: EVALUATE

### A Five-Stage Instructional Model

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Students use their experiences to construct and develop knowledge and meaning as they progress through each of the stages.

This model has two fundamental characteristics in common with most real-world learning: It involves learning by doing, and it asks learners to collaborate with peers and experts in meeting their responsibilities.

It's showtime now! The Evaluate lesson(s) provide opportunities for students to display, present, explain, report, broadcast, perform, and demonstrate the fruits of their hard work. The parenthetical plural calls attention to the fact that students will need time to share their projects, experiments, activities. Rarely can such meaningful sharing be done in a single class period. During presentations, non-presenting students should be active listeners/viewers.

### During a successful Evaluate, students:

- present, explain, and defend their work
- listen, respond, and assess or self-assess, depending on whether they are presenting or in the audience
- take notes and record responses in journals
- discuss the range of work, synthesize, and draw reasonable conclusions when appropriate
- ask new questions, pose new problems, outline new research topics
- provide positive, descriptive feedback to peers

### What Does a Good Evaluate Lesson Look Like?

The Evaluate stage should showcase the cumulative product of students' work. Teacher assessment and peer review sheets should be part of any presentation or performance or debate so that evidence of the performance and supportive feedback can be systematically and conveniently recorded for student conferences and reports. Students should also have a paper trail in their journals, notes, and drafts that may already have been collected or may be collected after the Evaluate sharing.

In other words, a successful Evaluate lesson should be one part assessment and one part celebration. It should give students an opportunity to demonstrate their mastery of the instructional units goals and exercise developing skills. A good Evaluate lesson also lays the foundation for future learning.

### A real-world example:

No one learns to ride a bike by simply hearing a lecture on it or just by reading the manual. You learn when you climb on a bike and wobble and fall. You learn faster when someone is coaching you, holding the handlebars or seat and then letting go, encouraging you when you fall, describing what he or she sees, finding other words for what you are supposed to be doing to keep your balance.

- **Engage**: getting that first opportunity to own and ride a bike; holding the bike in your living room or yard, putting a foot on one of the pedals; looking through the manual
- **Explore**: riding and falling for the first (and second or more times)
- **Explain**: getting instructions from your friends, family, or manual; riding with the assistance of a guiding hand
- **Elaborate**: riding without the guiding hand
- **Evaluate**: analyzing and adjusting until you get it right

# The 5Es Instructional Model

## Engage:

- First engage your students by an event or question related to the concept that you plan to introduce. This provides you with the opportunity to find out what students already know or what they think they know about the topic and concepts to be developed.

## Explore:

- Next allow your students to participate in activities to explore the concept. This exploration provides students with a common set of experiences and a broad range of experiences within which students can compare what they think about what they are observing and experiencing.

## Explain:

- Provides opportunities for students to connect their previous experienced and to begin to make conceptual sense of the main ideas of the module. This stage allows for the introduction of formal language, scientific terms, and content information that might help to clarify concepts and make students' previous experiences easier to describe and explain.

## Elaborate:

- Allow the students to elaborate and build on their understanding of concepts by extending them, applying them to new situations, and relating their previous experiences to new ones.

## Evaluate:

- The evaluation of students' conceptual understanding and ability to use skills begins with the engage and continues throughout each stage of the model. Combined with the students' written work and performance of tasks throughout the module, the evaluate lesson can serve as a summative assessment of what students know and can do at this point.

| What the Teacher Does | | |
|---|---|---|
| **Stage of the Instructional Model** | **That Is Consistent with the 5 E's Instructional Model** | **That Is Inconsistent with the 5 E's Instructional Model** |
| **Engage** | • Piques students' curiosity and generates interest<br>• Determines students' current understanding (prior knowledge) of a concept or idea<br>• Invites students to express what they think<br>• Invites students to raise their own questions<br>• Encourages students to compare their ideas with the ideas of others | • Introduces vocabulary<br>• Explains concepts<br>• Provides definitions and answers<br>• Provides closure<br>• Discourages students' ideas and questions |
| **Explore** | • Encourages student-to-student interaction<br>• Observes and listens to students as they interact<br>• Asks probing questions to redirect students' investigations when necessary<br>• Asks questions to help students make sense of their experiences<br>• Provides time for students to puzzle through problems<br>• Act as a resource for students | • Provides answers<br>• Proceeds too rapidly for students to make sense of their experiences<br>• Provides closure<br>• Tells students that they are wrong<br>• Gives information and facts that solve the problem<br>• Leads students step-by-step to a solution |
| **Explain** | • Encourages students to use their common experiences and data from the Engage and Explore lessons to develop explanations<br>• Asks questions that help students express understanding and explanations in their own words<br>• Requests justification (evidence) for students' explanations<br>• Provides time for students to compare their ideas with those of others and perhaps to revise their thinking<br>• Introduces terminology and alternative explanations after students express their ideas | • Neglects to solicit students' explanations<br>• Ignores data and information students gathered from previous lessons<br>• Dismisses students' ideas<br>• Accepts explanations that are not supported by evidence<br>• Introduces unrelated concepts or skills |
| **Elaborate** | • Focuses students' attention on conceptual connections between new and former experiences<br>• Encourages students to use what they have learned to explain a new event or idea<br>• Observes and provides support as students communicate their understanding to others<br>• Reinforces students' use of scientific terms and descriptions previously introduced<br>• Asks questions that help students draw reasonable conclusions from evidence and data | • Neglects to help students connect new and former experiences<br>• Provides definitive answers<br>• Tells students that they are wrong<br>• Leads students step-by-step to a solution |
| **Evaluate** | • Observes and records as students demonstrate their understanding of concept(s) and performance of skills<br>• Asks questions that help students see the relationship between a new situation and previous experiences<br>• Provides time for students to compare their ideas with those of others and perhaps to revise their thinking<br>• Interviews students as a means of assessing their developing understanding<br>• Encourages students to assess their own progress by comparing theircurrent understanding with their prior knowledge | • Tests vocabulary words, terms, and isolated facts<br>• Introduces new ideas or concepts<br>• Creates ambiguity<br>• Promotes open-ended discussion unrelated to the concept or skill |

## What Students Do

| Stage of the Instructional Model | That Is Consistent with the 5 E's Instructional Model | That Is Inconsistent with the 5 E's Instructional Model |
|---|---|---|
| **Engage** | • Become interested in and curious about the concept/topic<br>• Express current understanding of concept or idea<br>• Raise questions such as *What do I already know about this? What do I want to know about this? How could I find out?* | • Ask for the "right" answer<br>• Offer the "right" answer<br>• Insist on answers or explanations<br>• Seek closure |
| **Explore** | • Mess around with materials and ideas<br>• Conduct investigations in which they observe, describe, and gather and record data<br>• Try different ways to solve a problem or answer a question<br>• Acquire a common set of experiences with their classmates so they can compare results and ideas<br>• Compare their own ideas with those of others | • Let others do the thinking and exploring (passive involvement)<br>• Work quietly with little or no interaction with others (appropriate only when exploring ideas or feelings)<br>• Stop with one solution<br>• Demand or seek closure |
| **Explain** | • Explain concepts and ideas in their own words<br>• Base their explanations on evidence acquired during previous investigations<br>• Become involved in student-to-student conversations in which they explain their thinking to others and debate their ideas<br>• Reflect on and perhaps revise their ideas<br>• Record their ideas and current understanding<br>• Express their ideas using appropriate scientific language<br>• Compare their ideas with what scientists know and understand | • Propose explanations from thin air with no relationship to previous experiences<br>• Bring up irrelevant experiences and examples<br>• Accept explanations without justification<br>• Ignore or dismiss other plausible explanations<br>• Propose explanations without evidence to support their ideas |
| **Elaborate** | • Make conceptual connections between new and former experiences<br>• Use what they have learned to explain a new object, event, organism, or idea<br>• Connect ideas, solve problems, and apply their understanding in new situations<br>• Use scientific terms and descriptions<br>• Draw reasonable conclusions from evidence and data<br>• Add depth to their understanding of concepts and processes<br>• Communicate their understanding to others | • Ignore previous information or evidence<br>• Draw conclusions from thin air<br>• Use terminology inappropriately and without understanding |
| **Evaluate** | • Demonstrate what they understand about the concept(s) and how well they can implement a skill<br>• Compare their current thinking with that of others and perhaps revise their ideas<br>• Apply their understanding and knowledge in a unique, but related, situation<br>• Assess their own progress by comparing their current understanding with their prior knowledge<br>• Ask new questions that take them deeper into a concept or new topic area | • Disregard evidence or previously accepted explanations in drawing conclusions<br>• Offer only yes-or-no answers, memorized definitions or explanations as answers<br>• Fail to express satisfactory explanations in their own words<br>• Introduce new, irrelevant topics |

## LESSON TITLE

# INTRODUCING INQUIRY AND THE NATURE OF SCIENCE

## UNIFYING THEME

Scientific Inquiry

## FOCUS QUESTION

How can we use observation and prediction to understand inquiry and the nature of science?

## LESSON OVERVIEW

This activity introduces basic procedures involved in inquiry and concepts describing the nature of science. In the first portion of the activity the teacher uses a numbered cube to involve students in asking a question—what is on the bottom?— and the students propose an explanation based on their observations. Then the teacher presents the students with a second cube and asks them to use the available evidence to propose an explanation for what is on the bottom of this cube. This activity provides students with opportunities to learn the abilities and understandings aligned with the Science Practices of the Next Generation Science Standards.

## LESSON DURATION

The activity requires a total of 90 minutes to complete.

Engage.............................. 15 minutes
Explore............................. 30 minutes
Explain............................. 10 minutes
Elaborate.......................... 15 minutes
Evaluate............................ 20 minutes

## LEARNING OBJECTIVES

Students will be able to:

- identify questions that can be answered through scientific investigations,
- design and conduct a scientific investigation,
- use appropriate tools and techniques to gather, analyze, and interpret data,
- develop descriptions, explanations, predictions, and models using evidence,
- think critically and logically to make relationships between evidence and explanations,
- recognize and analyze alternative explanations and predictions,
- communicate scientific procedures and explanations.

Students will develop the understanding that:

- Different kinds of questions suggest different kinds of scientific investigations.
- Current scientific knowledge and understanding guide scientific investigations.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.
- Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world.

## STANDARDS

This activity provides all students with opportunities to progress towards these Next Generation Science Standard Practices:

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models.
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

## PREPARATION

1. Cut out and tape together a number cube for each group. Tape each down to a piece of construction paper to prevent students from seeing the bottom.
2. Do the same with the name cubes.
3. Prepare a station with probes and mirrors.

## MATERIALS

Student (individual)

| Item | No. |
|---|---|
| Student Journal | 1 |
| Text Rendering Steps | 2 |
| Penicillin, the Wonder Drug | 3 |

Student (per group of three)

| Item | No. |
|---|---|
| Number cube | 1 |
| Name cube | 1 |
| Small probe | 1 |
| Small pocket mirror | 1 |

# SCIENCE BACKGROUND FOR TEACHERS

The pursuit of scientific explanations often begins with a question about a natural phenomenon. Science is a way of developing answers, or improving explanations, for observations or events in the natural world. The scientific question can emerge from a child's curiosity about where the dinosaurs went or why the sky is blue. Or the question can extend scientists' inquiries into the process of extinction or the chemistry of ozone depletion.

Once the question is asked, a process of scientific inquiry begins, and there eventually may be an answer or a proposed explanation. Critical aspects of science include curiosity and the freedom to pursue that curiosity. Other attitudes and habits of mind that characterize scientific inquiry and the activities of scientists include intelligence, honesty, skepticism, tolerance for ambiguity, openness to new knowledge, and the willingness to share knowledge publicly.

Scientific inquiry includes systematic approaches to observing, collecting information, identifying significant variables, formulating and testing hypotheses, and taking precise, accurate, and reliable measurements. Understanding and designing experiments are also part of the inquiry process.
Scientific explanations are more than the results of collecting and organizing data. Scientists also engage in important processes such as constructing laws, elaborating models, and developing hypotheses based on data. These processes extend, clarify, and unite the observations and data and, very importantly, develop deeper and broader explanations. Examples include the taxonomy of organisms, the periodic table of the elements, and theories of common descent and natural selection.

One characteristic of science is that many explanations continually change. Two types of changes occur in scientific explanations: new explanations are developed, and old explanations are modified.
Just because someone asks a question about an object, organism, or event in nature does not necessarily mean that person is pursuing a scientific explanation. Among the conditions that must be met to make explanations scientific are the following:

- *Scientific explanations are based on empirical observations or experiments*. The appeal to authority as a valid explanation does not meet the requirements of science. Observations are based on sense experiences or on an extension of the senses through technology.
- *Scientific explanations are made public.* Scientists make presentations at scientific meetings or publish in professional journals, making knowledge public and available to other scientists.
- *Scientific explanations are tentative.* Explanations can and do change. There are no scientific truths in an absolute sense.
- *Scientific explanations are historical.* Past explanations are the basis for contemporary explanations, and those, in turn, are the basis for future explanations.
- *Scientific explanations are probabilistic*. The statistical view of nature is evident implicitly or explicitly when stating scientific predictions of phenomena or explaining the likelihood of events in actual situations.
- *Scientific explanations assume cause-effect relationships*. Much of science is directed toward determining causal relationships and developing explanations for interactions and linkages between objects, organisms, and events. Distinctions among causality, correlation, coincidence, and contingency separate science from pseudoscience.
- *Scientific explanations are limited*. Scientific explanations sometimes are limited by technology, for example, the resolving power of microscopes and telescopes. New technologies can result in new fields of inquiry or extend current areas of study. The interactions between technology and advances in molecular biology and the role of technology in planetary explorations serve as examples.

Science cannot answer all questions. Some questions are simply beyond the parameters of science. Many questions involving the meaning of life, ethics, and theology are examples of questions that science cannot answer.

## ENGAGE

- Icebreaker: TAPPS and Whole-class Discussion 15 minutes

1. Have students work in pairs
2. Review the TAPPS directions
3. Give each student a postcard
4. Ask, “How does this image resonate with the concept of scientific inquiry?”
5. Give 2 minutes for the first Speaker; then give 2 minutes for the partner
6. Ask for Listeners to share what they heard

Debrief the activity afterwards with any of these questions:

- How did it feel to do this activity?
- How did it feel to share what someone else said?
- What was the most surprising thing you heard?

## EXPLORE

- Cooperative Teams 30 minutes

Group students into teams of three. Place the cubes in the center of the table where the students are working. The students should not touch, turn, lift, or open the cube. Allow students time to explore the cube and to write down observations in their journals. Some observations or statements of fact that the students may make include:

- The cube has six sides.
- The cube has five exposed sides.
- The numbers and dots are black.
- The exposed sides have numbers 1, 3, 4, 5, and 6.
- The opposite sides add up to seven.
- The even-numbered sides are shaded.
- The odd-numbered sides are white.

Tell the students they have to identify a question associated with the cube. Allow the students to write their questions in their journals. Likely questions include:

- What is in the cube?
- What is on the bottom of the cube?
- What number is on the bottom?

You should direct students to the general question, *what is on the bottom of the cube*? Tell the students that they will have to answer the question by proposing an explanation, and that they will have to convince you and other students that their answer is *based on evidence*. (Evidence refers to observations the group can make about the visible sides of the cube.) Ask students to use their observations (the data) to predict what is on the bottom of the cube. The student groups should be able to make a statement such as: *We predict there is a 2 on the bottom*. Students should record their evidence for this conclusion in their journals. For example, they might base their conclusion on the observation that the exposed sides are 1, 3, 4, 5, and 6, and because 2 is missing from the sequence, they conclude it is on the bottom. Use this opportunity to have the students develop the idea that combining two different but logically related observations creates a stronger explanation. For example, 2 is missing in the sequence (that is, 1, _, 3, 4, 5, 6) and that opposite sides add up to 7 (that is, 1—6; 3—4; _—5) and because 5 is on top, and 5 and 2 equal 7, 2 could be on the bottom.

Begin to put the cube away without showing the bottom or allowing students to dismantle it. Explain that scientists often are uncertain about their proposed answers, and often have no way of knowing the absolute answer to a scientific question. Examples such as the exact ages of stars and the reasons for the extinction of prehistoric organisms will support the point. Students will most likely object at the point: they will want to know what's on the bottom. Use your judgement as to whether they can see the bottom.[1]

# EXPLAIN

- Whole Class Discussion 10 minutes

Begin with an explanation of how the activity simulates scientific inquiry and provides a model for science. Ask students to share what they did to reach their conclusions. Key points could include:

- Asking questions
- Using observations to construct explanations (answers to the questions). The more observations you had that supported your proposed explanation, the stronger your explanation, even if you could not confirm the answer by examining the bottom of the cube.
- Discussing with others.

The activity does not explicitly describe "the scientific method." The students had to work to answer the question and probably did it in a less than systematic way. Identifiable elements of a method—such as observation, data, and hypotheses—were clear but not applied systematically. You can use the experiences to point out and clarify scientific uses of terms such as observation, hypotheses, and data.

Tie it back to the People Hunt activity: how was that like scientific inquiry? How was it different?

# ELABORATE

- Text-Rendering Discussion 15 minutes

Explain that you will now examine an actual scientific discovery. Move students into a circle. Distribute the Text Rendering Steps and read them aloud to the students. Ask if there are any questions and allow for open discussion. Wherever possible, deflect questions to other students. Distribute the reading on the discovery of Penicillin. Read the passage aloud while students read along silently. Have students follow the steps of the text-rendering process.

# EVALUATE

- Cooperative Teams 20 minutes

The main purpose of the second cube is to allow student to apply the concepts and skills introduced in the earlier activities and to introduce the role of prediction, experiment, and the use of technology in scientific inquiry. The problem is the same as the first cube: to predict what is on the bottom. Divide the class into groups of three again and instruct them to make observations, record these in their journals, and propose an answer about the bottom of the cube. Student groups should record their factual statements about the second cube. Let students identify and organize their observations. If the students are becoming too frustrated, provide helpful suggestions. Essential data from the cube include the following:

- Names and numbers are in black.
- Exposed sides have either a male or female name.
- Opposing sides have a male name on one side and a female name on the other.
- Names on opposite sides begin with the same letters.
- The number in the upper-right corner of each side corresponds to the number of letters in the name on that side.
- The number in the lower-left corner of each side corresponds to the number of the first letters that the names on opposite sides have in common.
- The number of letters in the names on the five exposed sides progresses from three (Rob) to seven (Roberta).

[1] adapted from Teaching About Evolution and the Nature of Science, pg. 68

Four names, all female, could be on the bottom of the cube: Fran, Frances, and Francine. Because there are no data to show the exact name, groups might have different hypotheses. Tell the student groups that scientists use patterns in data to make predictions and then design an experiment to assess the accuracy of their prediction. This process also produces new data.

Tell groups to use their observations (the data) to make a prediction of the number in the upper-right corner of the bottom. The predictions will most likely be 4, 7, or 8. Have the team decide which corner of the bottom they wish to inspect and why they wish to inspect it. The students might find it difficult to determine which corner they should inspect. Let them struggle with this and even make a mistake—this is part of science!

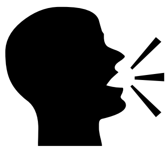
Ask one student from each group to obtain a probe and a mirror. Student may lift the designated corner less than one inch and use the mirror to look under the corner. This simulates the use of technology in a scientific investigation. The groups should describe the data they gained by the "experiment." Note that the students used technology to expand their observations and understanding about the cube, even if they did not identify the corner that revealed the most productive evidence.

If students observe the corner with the most productive information, they will discover an 8 on the bottom. This observation will confirm or refute the students' working hypotheses. Francine is a possible name on the bottom. The students propose their answer to the question and design another experiment to answer the question. Begin to put the cube away without revealing the bottom. Have each of the student groups present brief reports on their investigation. After the teams have presented their reports, allow them to see the bottom of their cubes. While some may have predicted Francine, it’s not likely that any predicted Francene, the name on the bottom. Take this opportunity to discuss scientific predictions and how certain scientists can be. [2]

[2] adapted from Teaching About Evolution and the Nature of Science, pg. 69

# TAPPS

# Thinking Aloud Paired Problem Solving



## Speaker:

- Say aloud everything you are thinking as you solve the problem

## Listener:

- Listen
- Take notes on what your speaker is saying
- Remind the speaker to talk if there is silence
- You may ask clarifying questions, but do not help solve the problem
- Be prepared to share what you heard

National School Reform Faculty

Harmony Education Center

www.nsrfharmony.org

# Text Rendering Experience

*Developed in the field by educators affiliated with NSRF.*

**Purpose**
To collaboratively construct meaning, clarify, and expand our thinking about a text or document.

**Roles**
A facilitator to guide the process.
A scribe to track the phrases and words that are shared.

**Set Up**
Take a few moments to review the document and mark the sentence, the phrase, and the word that you think is particularly important for our work.

**Steps**

1. First Round: Each person shares a *sentence* from the document that he/she thinks/feels is particularly significant.

2. Second Round: Each person shares a *phrase* that he/she thinks/feels is particularly significant. The scribe records each phrase.

3. Third Round: Each person shares the *word* that he/she thinks/feels is particularly significant. The scribe records each word.

4. The group discusses what they heard and what it says about the document.

5. The group shares the words that emerged and any new insights about the document.

6. The group debriefs the text rendering process.

# Excerpted from ***Penicillin*, The Wonder Drug**

By George Wong

Today, penicillin is a common treatment for many diseases, and it is one that has been developed recently. The idea of using fungal products, such as penicillin, to produce medicine is a relatively new one, but fungi have been used in many folk remedies for a long period of time, even though the incorporation of fungi into the remedy was not specifically known. Over three thousand years ago, the Chinese had put moldy soybean curd on boils and other types of skin infections. Other cultures have placed warm earth, which contains molds and other fungi, as first aid in injuries. So, although the concept of antibodies is relatively recent, the indirect use of fungi for medicinal purposes is not.

Penicillin was discovered by Dr. Alexander Fleming in 1928. Before Fleming, there were a series of observations that influenced his research and allowed him to come to the correct conclusion.

Discoveries in science often involve knowledge that has been gained over a long period of time so that all discoveries, today, have come about because we have "stood on the shoulders of giants that have come before us."

In the late nineteenth century Louis Pasteur put forth the concept of the germ theory of disease. Not until then was there any concerted effort made that would destroy the microorganisms that were responsible for the actual causes of diseases. One of the most common problems that occurred, and still occurs today, was the contamination of bacterial cultures by other microorganisms, especially fungi. These contaminations led to a number of observations beginning in the late 1800s.

As early as 1920, Fleming was searching for antibacterial agents. During the First World War, he had witnessed the deaths of many soldiers not from the wounds that were received during combat, but from septicemia or in layman's term, blood poisoning, following successful operations on those wounds.

In 1928, he was researching the properties of the group of bacteria known as staphylococci and became another in the long line of scientists to benefit from a seemingly *chance* observation. His problem during this research was the frequent contamination of culture plates with airborne molds. However, he was also a sloppy scientist as well. Cultures that he worked on were constantly forgotten, in his lab, which was normally in a state of great disorder. One day he observed a contaminated culture plate and noted that the *Staphylococci* bacteria had burst in the area immediately surrounding an invading mold growth. He realized that something in the mold was inhibiting growth of the surrounding bacteria.

Although, Fleming was not very knowledgeable about fungi, he was able to identify it as a species of *Penicillium*. Subsequently Fleming isolated an extract from the mold and he named it penicillin.

Others had made the same chance observation that led Fleming to his discovery, but their only response to the contamination was that it had ruined their experiment, discarded the cultures and thought nothing more of it.

# The TASC Test Science

The Test Assessing Secondary Completion™ — the TASC test is designed to assess the high school performance expectations in the Next Generation Science Standards (NGSS). A PDF of the NGSS arranged by Disciplinary Core Idea is available online at: http://www.nextgenscience.org/next-generation-science-standards

The NGSS performance expectations state what all learners should be able to do in order to demonstrate their understanding of science. Each NGSS performance expectation integrates a Science and Engineering Practice, one or more Disciplinary Core Ideas, and a Crosscutting Concept. Each NGSS performance expectation also includes a Clarification Statement and an Assessment Boundary to provide further information for the purposes of curriculum, instruction, and assessment.

The TASC test Science assessment will include items for the disciplines of Physical Sciences, Life Sciences, and Earth and Space Sciences. Each discipline is subdivided into several Core Ideas, which each contain multiple performance expectations. Each test item assesses one performance expectation. Items may require recalling knowledge, applying knowledge and skills, or reasoning.

The number of test items per Core Idea is proportional to the number of performance expectations within the Core Idea. As a result, each Core Idea will have about 2-5 items on a given test. A given test will not necessarily include items for every performance expectation present in the NGSS, though any performance expectation is potentially assessable.

## High Emphasis:

### Life Sciences

- Core Idea: HS-LS1 From Molecules to Organisms: Structures and Processes
- Core Idea: HS-LS2 Ecosystems: Interactions, Energy, and Dynamics
- Core Idea: HS-LS3 Heredity: Inheritance and Variation of Traits
- Core Idea: HS-LS4 Biological Evolution: Unity and Diversity

### Earth and Space Sciences

- Core Idea: HS-ESS1 Earth's Place in the Universe
- Core Idea: HS-ESS1 Earth's Systems
- Core Idea: HS-ESS1 Earth and Human Activity

## Medium Emphasis:

### Physical Sciences

- Core Idea: HS-PS1 Matter and Its Interactions
- Core Idea: HS-PS2 Motion and Stability: Forces and Interactions
- Core Idea: HS-PS3 Energy
- Core Idea: HS-PS4 Waves and Their Applications in Technologies for Information Transfer

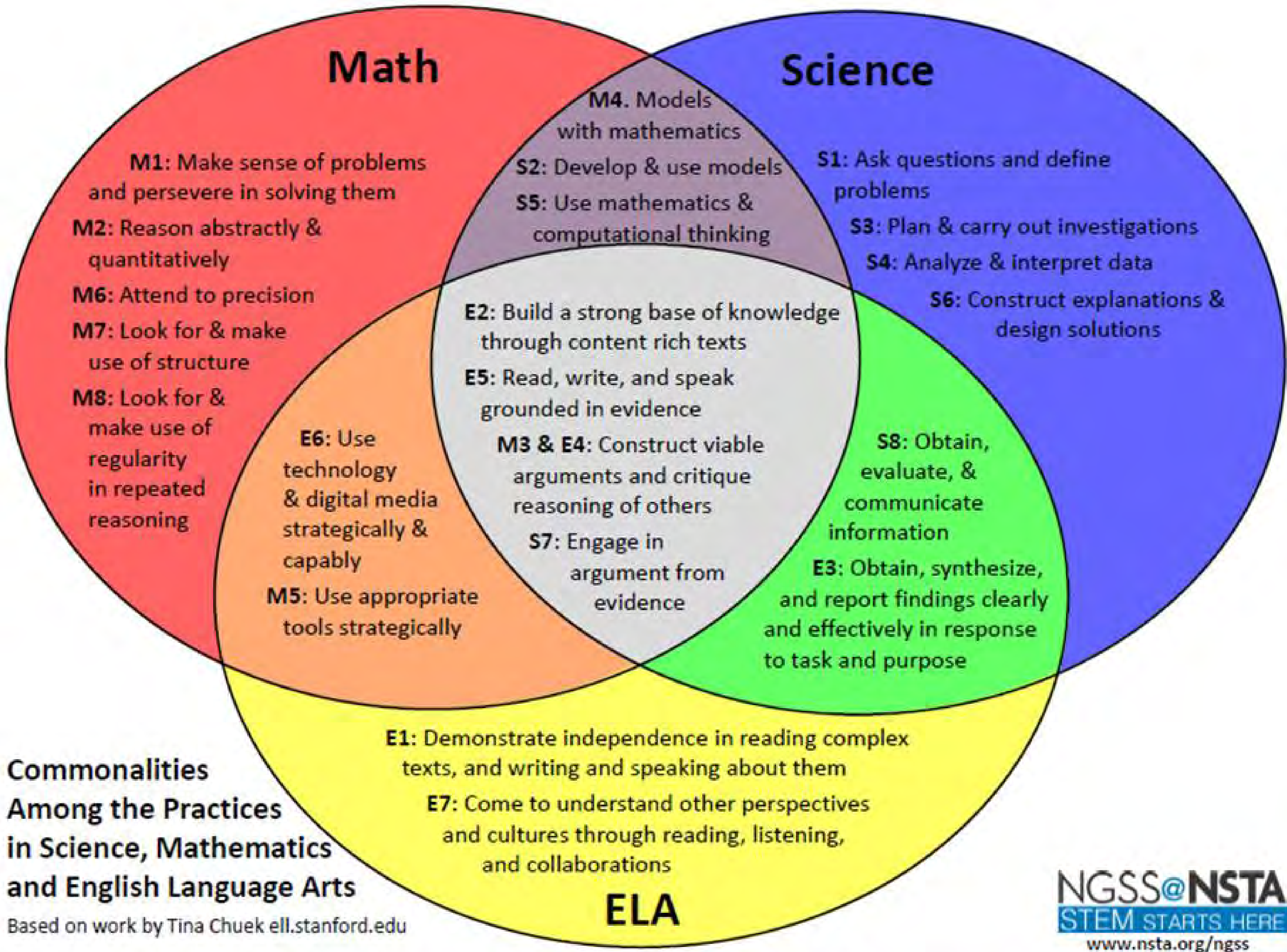
**Note:** The TASC test will not include test items to directly assess the performance expectations in the Core Idea of HS-ETS1 Engineering Design. However, some performance expectations in Physical Sciences, Life Sciences, and Earth and Space Sciences integrate engineering through a Practice or Disciplinary Core Idea. Items aligned to those performance expectations may require examinees to demonstrate their understanding of science through the application of the engineering design process such as defining and delimiting a problem, designing solutions to a problem, and evaluating and optimizing design solutions.

# Practices in Mathematics, Science, and English Language Arts*

| Math | Science | English Language Arts |
|---|---|---|
| **M1.** Make sense of problems and persevere in solving them.<br>**M2.** Reason abstractly and quantitatively.<br>**M3.** Construct viable arguments and critique the reasoning of others.<br>**M4.** Model with mathematics.<br>**M5.** Use appropriate tools strategically.<br>**M6.** Attend to precision.<br>**M7.** Look for and make use of structure.<br>**M8.** Look for and express regularity in repeated reasoning. | **S1.** Asking questions (for science) and defining problems (for engineering).<br>**S2.** Developing and using models.<br>**S3.** Planning and carrying out investigations.<br>**S4.** Analyzing and interpreting data.<br>**S5.** Using mathematics, information and computer technology, and computational thinking.<br>**S6.** Constructing explanations (for science) and designing solutions (for engineering).<br>**S7.** Engaging in argument from evidence.<br>**S8.** Obtaining, evaluating, and communicating information. | **E1.** They demonstrate independence.<br>**E2.** They build strong content knowledge.<br>**E3.** They respond to the varying demands of audience, task, purpose, and discipline.<br>**E4.** They comprehend as well as critique.<br>**E5.** They value evidence.<br>**E6.** They use technology and digital media strategically and capably.<br>**E7.** They come to understanding other perspectives and cultures. |

* The Common Core English Language Arts uses the term "student capacities" rather than the term "practices" used in Common Core Mathematics and the Next Generation Science Standards.

NGSS@NSTA
STEM STARTS HERE


Math
Science
ELA
M1: Make sense of problems and persevere in solving them
M2: Reason abstractly & quantitatively
M6: Attend to precision
M7: Look for & make use of structure
M8: Look for & make use of regularity in repeated reasoning
M4. Models with mathematics
S2: Develop & use models
S5: Use mathematics & computational thinking
S1: Ask questions and define problems
S3: Plan & carry out investigations
S4: Analyze & interpret data
S6: Construct explanations & design solutions
E2: Build a strong base of knowledge through content rich texts
E5: Read, write, and speak grounded in evidence
M3 & E4: Construct viable arguments and critique reasoning of others
S7: Engage in argument from evidence
E6: Use technology & digital media strategically & capably
M5: Use appropriate tools strategically
S8: Obtain, evaluate, & communicate information
E3: Obtain, synthesize, and report findings clearly and effectively in response to task and purpose
E1: Demonstrate independence in reading complex texts, and writing and speaking about them
E7: Come to understand other perspectives and cultures through reading, listening, and collaborations
Commonalities Among the Practices in Science, Mathematics and English Language Arts
Based on work by Tina Chuek ell.stanford.edu
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www.nsta.org/ngss

# The "Dark" Side of the Moon

Four students are assembling a photo collage of pictures taken of the moon from the Griffith Observatory in California. They notice that only pictures from one side of the moon are available to them. One of them notes that only one side of the moon can be seen from Earth. The students had different ideas on why this was the case. This is what they said:

**Huilang:** "I think that the time it takes for the moon to rotate on its axis is exactly the same amount of time it takes for the Earth to rotate on its axis, so only the same area of the moon is visible to the observatory."

**Daquan:** "I feel it is because the moon does not rotate, resulting in the dark side of the moon. The side of the moon we can see actually does face us at certain times of its orbit around the Earth, but since the sun does not reflect off of the dark side of the moon, we cannot see it."

**Nunzio:** "Perhaps it is because the time it takes the Moon to revolve around the Earth is the same as the amount of time it takes to rotate, and then only one side of the moon ever faces the Earth."

**Holden:** "I think it is because the Earth's tilt only allows those of us in the Northern Hemisphere to see one side of the moon. The term 'Dark Side of the Moon' only exists because it was coined in the Northern Hemisphere. People in the Southern Hemisphere can probably see side of the moon which we cannot see."

Who do you think has the best idea about the dark side of the moon?

Explain why you think that it is the best idea.

# The Sun-Earth-Moon Systems

Understanding of lunar phases and frames of reference

Premise behind the lesson: If students develop an understanding of the relative positions of the Sun, Earth, and Moon, then they can reason their way through an explanation of the phases of the moon.

Students should understand that the observed phase of the moon is determined by the moon's position relative to the Earth and Sun.

Students will understand that the different phases of the moon depend on the position of the Earth and Moon in relation to the Sun.

**Instructional Time:** 1 Hour(s)

**Lesson Plan Template:** 5E Model

**Keywords:** Moon, phases, relative position, lunar, Sun, clockwise, counterclockwise, rotation, revolution.

**NGSS:** Students who demonstrate understanding can:

**MS-ESS1-1.** **Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.** [Clarification Statement: Examples of models can be physical, graphical, or conceptual.]

## Science and Engineering Practices

**Developing and Using Models**

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

## Disciplinary Core Ideas

**ESS1.A: The Universe and Its Stars**

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (MS-ESS1-2)

**Systems and System Models**

- Models can be used to represent systems and their interactions. (MS-ESS1-2)

## LESSON CONTENT

### Learning Objectives:

- Students will understand the positions of the Earth, the Moon and the Sun in relation to the phases of the moon.
- Students will understand that the different phases of the Moon depend on the position of the Earth and Moon in relation to the Sun.

### Guiding Questions:

- What causes the light we see when we look at the Moon?
- What causes the different phases of the Moon?
- What does the term relative position mean?
- What would the Moon be like if our relative positions never changed?

- **Engage: What object, event, or questions will the teacher use to trigger the students' curiosity and engage them in the concepts**

  Place a light source in a clear area of the classroom to represent the Sun. Turn off all other lights and draw any shades on the windows. Select a student to represent Earth and have this student stand in a clear area front of the light source. As an imitation for the United States, the student's face will represent Nebraska, so the student's left shoulder represent New York and the student's right shoulder will represent California.

  TQ: What must the student portraying the Earth have to do to simulate one day?

  TQ: In which way does Earth rotate?

  When viewed from the North Pole or Polaris (northern star), all the planets in the solar system revolve around the sun in a counterclockwise direction. Most rotate on their axis counterclockwise as well, the exceptions being Venus and Uranus.

  Ask the student representing Earth to rotate.

  TQ: What can you tell?

  TQ: What else does Earth need to do to act out one day?

- **Explore: What will the students do to explore the concepts and skills being developed through the lesson?**

  We have just seen what Earth does to represent one day.

  Q: What does the Moon do to represent one lunar day? /Have students discuss in groups.

  **The Vast Distances of Empty Space**

  - The diameter of the Sun is approximately 850,000 miles and is located roughly 93 million miles from the Earth.
  - If the Sun were to be represented by a 6 inch wide light bulb, how far away would the Earth be from the Sun?
    - 850,000 miles/6 inches = 141,000 miles per inch (scale)
    - 93,000,000 miles/141,000 (scale)= 660 inches
    - 660 inches = 55 feet
  - The Earth has a diameter of roughly 8,000 miles. If you were to use the same scale, how big would the Earth be?
    - 8,000 miles/141,000 (scale) = .05678 of an inch
    - .05678 of an inch is about the same as the thickness of nail polish.

  - The diameter of the Earth is approximately 8,000 miles and is located roughly 286,000 miles from the Moon.
  - If the Earth were to be represented by a 6 inch wide ball, how far away would the Moon be from the Earth?
    - 8,000 miles/6 inches = 1,333 miles per inch (scale)
    - 286,000 miles/1,333 (scale)= 215 inches
    - 215 inches = 17.9 feet
  - The Moon has a diameter of roughly 2,157 miles. If you were to use the same scale, how big would the Moon be?
    - 2,157 miles/1,333 (scale) = 1.618 inches

After a whole class discussion students should have clear that the Moon will appear to travel roughly 1/29$^{th}$ of the way around its orbit in a counterclockwise direction. The Moon rotates in its axis in the same amount of time it takes for it to revolve around the Earth, which causes the same side to always face the Earth. The term "dark side of the moon" is therefore misleading, as that represents the side of the Moon which is not visible from Earth. This side, however, does in fact get sunlight.

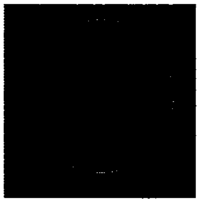
All of the major moons of the solar system orbit their planets in a counterclockwise direction, the exception being Triton of Jupiter.

Ask students to examine now the Moon phases by looking at the orientation of the Sun, Earth, and Moon discussed and possibly depicted before.

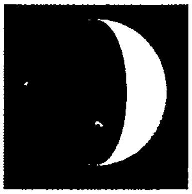
Students need to imagine that they are looking at the Moon from the perspective of Nebraska (the face of the student portraying Earth). As the Moon travels around Earth, this frame of reference will allow them to see the phases of the moon.

Tell students that they need to use a model to represent the phases of the moon over one month.

**Go through the 8 major phases of the moon with your students.**

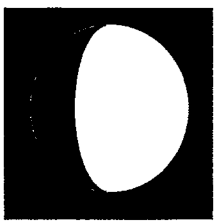
- 

  New moon- Moon is between the Sun and the Earth and they see the shadowed side of the moon. A solar eclipse occurs in this phase when the Moon blocks light from the Sun from reaching a portion of the Earth. Students can close one eye and simulate this event.

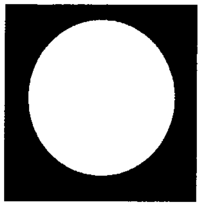


- Waxing crescent- rotating from a new moon toward a first quarter, backwards "c" shape will appear on the moon.

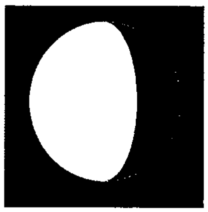
- First quarter- right half of the side of the Moon facing Earth is lit. The right shoulder is point towards the sun.



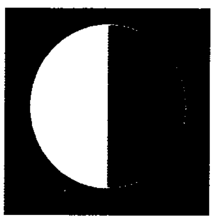
- Waxing gibbous- rotating from a first quarter to a full moon.



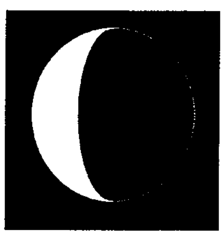
- Full moon- Earth is between the Moon and the Sun, the entire lit side of the moon is visible on Earth, (students' backs are to the sun and moons are lifted up to be lit). A lunar eclipse occurs when the Moon passes through the earth's shadow. Have your students simulate this event.



- Waning gibbous- rotating from a full Moon to a last quarter, less and less of the Moon is lit each night



- Last quarter- left half of the side of the Moon facing the Earth is lit, left shoulder is pointing to the Sun.



- Waning crescent- rotating from a last quarter to a new Moon, a "c" shape of light is seen on the left side of the Moon.

Evaluate the lesson by naming a moon phase and having your students rotate until they are in the correct phase. Jumble the phases to make it more of a challenge. Also include the two eclipses and the correct moon phases when they occur.

TQ: If the Moon passes between the Earth and the Sun during the New Moon, why isn't there a Solar Eclipse every month?

The Moon's orbit around the Earth is not on the same plane as the Earth's orbit around the Sun. Its orbit is tilted about 5% in relation to the Earth's orbit around the Sun. So the Moon does cross the exact plane of the Earth and Sun twice during each of its orbits around the Earth. If this crossing occurs, during the New moon phase, then a solar eclipse may occur. If this crossing occurs during the Full moon phase, a lunar eclipse may occur. At all other times, its crossing of the plane goes unnoticed.

Solar and lunar eclipses occur between 2 to 5 times per year.

- **Explain: What will the students and teacher do so students have opportunities to clarify their ideas, reach a conclusion or generalization, and communicate what they know to others?**

  Randomly pick students to choose a moon phase and get into position.

  Select another student to name and explain the phase that the first student is in.

  You can reverse this as well by choosing a students and calling out a phase to have them simulate.

- **Elaborate: What will the students do to apply their conceptual understanding and skills to solve a problem, make a decision, perform a task, or make sense of new knowledge?**

  Students can illustrate and label the phases of the Moon, explaining the relative position of the sun, Earth and Moon.

- **ASSESSMENT**

- **Formative Assessment:**
  As we begin our lesson, we will discuss the position of the Earth and Moon. As we move through the lesson, students will have the opportunity to show what they know as they rotate around the sun.

- **Feedback to Students:**
  Students will be working in groups so they will be constantly observing and correcting each other. Facilitator will also be asking questions as they move from group to group.

- **Summative Assessment:**
  Students will have the opportunity to quiz each other on the positioning of the earth, moon and sun as well as illustrating their findings and explaining their illustrations.

## ACCOMMODATIONS & RECOMMENDATIONS

- **Accommodations:** A smaller light source can be placed on a table and students can rotate the Moon around the source using their other finger as the Earth.

  Students can draw the phases of the Moon in relation to the Sun and Earth.

- **Extensions:** Students can observe the actual Moon phase for the evening and write a descriptive paragraph of how they could simulate the same phase.

  Students can chart the phases of the Moon for a full lunar cycle.

- **Some Resources:**

  CPALMS *State of Florida's official source for standards information and course descriptions.*

  http://www.sems.und.edu/index_MoonPhases.php

  http://quizlet.com/15003882/the-sun-earth-moon-system-flash-cards/

  *A Sun-Earth-Moon. activity to develop student understanding of lunar phases and frames of references*

  *By Scott Ashmann*

  *Inquiry, Argumentation and the Phases of the Moon.*

  *By Cady B. Hall and Victor Sampson*

# How Much Do You Weigh In Space?

Gravity is a universal, natural force that attracts objects to each other. Originally defined by Isaac Newton and later redefined by Albert Einstein, gravity is basically the natural force of attraction between two objects. Two factors determine the magnitude of the gravitational force between two objects: 1) their masses and 2) the separation distance between them. Gravity is the pull toward the center of an object, for example a planet or a moon. When you weigh yourself, you are measuring the amount of gravitational attraction exerted on you by Earth. The moon has a weaker gravitational attraction than the Earth, so you should weigh less on the moon.

Isaac Newton showed that the planets do not fly off into space because the gravitational attraction between the sun and each planet hold them close to each other. This attracting force exists between objects because of their mass. The greater the mass, the greater the attraction of gravity. Since every planet has mass, every planet exerts a gravitational force on nearby objects.

For this activity, there is a gravitational force of attraction between the planet and a person standing on that planet's surface. Therefore, people have different weights on different planets.

***You are traveling to various celestial bodies; use the chart below to calculate your weight given that your mass is constant.***

**Weight = mass × gravitational force**

| Planet | Multiply your "earth weight" by: | Your "new weight" |
|---|---|---|
| Mercury | 0.4 | |
| Venus | 0.9 | |
| Earth | 1 | |
| Moon | 0.17 | |
| Mars | 0.4 | |
| Jupiter | 2.5 | |
| Saturn | 1.1 | |
| Uranus | 0.8 | |
| Neptune | 1.2 | |

1. Given that Mercury is smaller than Mars, why do you weigh the same on both planets?

## Planetary Fact Sheet - Formula: $F = m/r^2$

| | MERCURY | VENUS | EARTH | MOON | MARS | JUPITER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|---|---|---|---|---|---|---|
| Mass | 0.0553 | 0.815 | 1 | 0.0123 | 0.107 | 317.8 | 95.2 | 14.5 | 17.1 | 0.0022 |
| Diameter | 0.383 | 0.949 | 1 | 0.2724 | 0.532 | 11.21 | 9.45 | 4.01 | 3.88 | 0.187 |
| Density | 0.984 | 0.951 | 1 | 0.605 | 0.713 | 0.240 | 0.125 | 0.230 | 0.297 | 0.332 |
| Gravity | 0.378 | 0.907 | 1 | 0.166 | 0.377 | 2.36 | 0.916 | 0.889 | 1.12 | 0.059 |
| Escape Velocity | 0.384 | 0.926 | 1 | 0.213 | 0.450 | 5.32 | 3.17 | 1.90 | 2.10 | 0.098 |
| Rotation Period | 58.8 | -244 | 1 | 27.4 | 1.03 | 0.415 | 0.445 | -0.720 | 0.673 | 6.41 |
| Length of Day | 175.9 | 116.8 | 1 | 29.5 | 1.03 | 0.414 | 0.444 | 0.718 | 0.671 | 6.39 |
| Distance from Sun | 0.387 | 0.723 | 1 | 0.00257* | 1.52 | 5.20 | 9.58 | 19.20 | 30.05 | 39.24 |
| Perihelion | 0.313 | 0.731 | 1 | 0.00247* | 1.41 | 5.03 | 9.20 | 18.64 | 30.22 | 30.15 |
| Aphelion | 0.459 | 0.716 | 1 | 0.00267* | 1.64 | 5.37 | 9.96 | 19.75 | 29.89 | 48.02 |
| Orbital Period | 0.241 | 0.615 | 1 | 0.0748 | 1.88 | 11.9 | 29.4 | 83.7 | 163.7 | 248.0 |
| Orbital Velocity | 1.61 | 1.18 | 1 | 0.0344 | 0.810 | 0.439 | 0.325 | 0.229 | 0.182 | 0.158 |

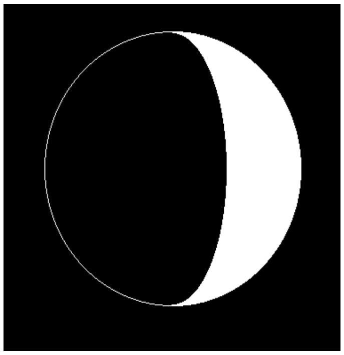
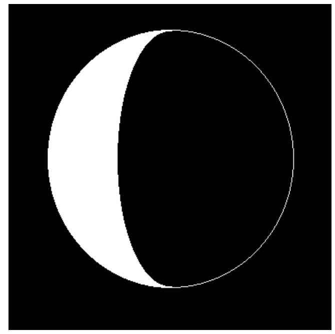
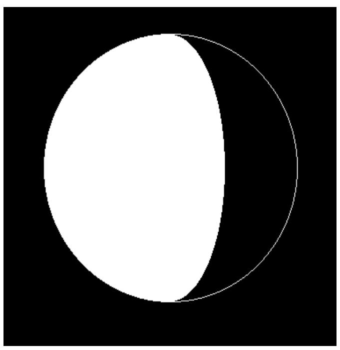
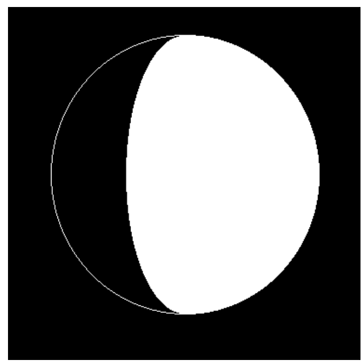
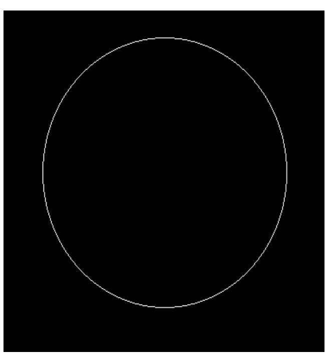
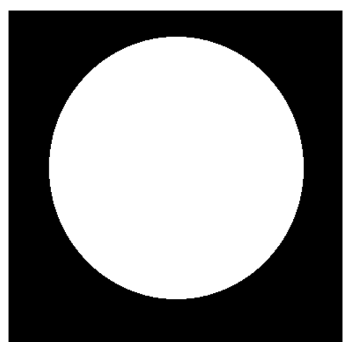
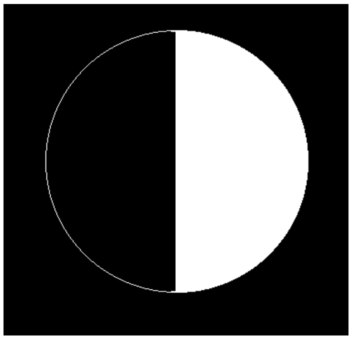
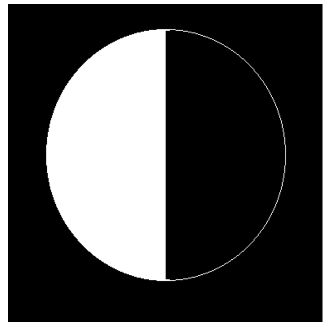
F = gravitational force    m = planet's mass    r = radius of planet

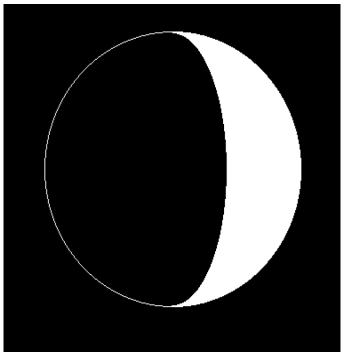
2. Use the evidence from your planetary fact sheet above to make a conjecture as to why both planets have a similar gravitational force.

3. Use the planetary fact sheet to investigate the comparison of the mass of Venus to the mass of the Earth.

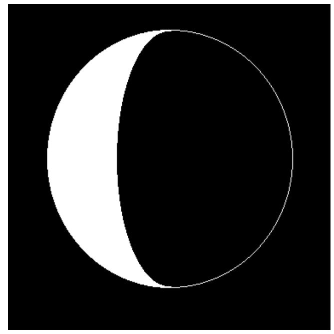
4. Use the planetary fact sheet to investigate the comparison of the radius of Saturn to the radius of the Earth.

5. Explain why your Earth weight is the same as your mass if Weight = mass × gravitational force



Waxing Crescent



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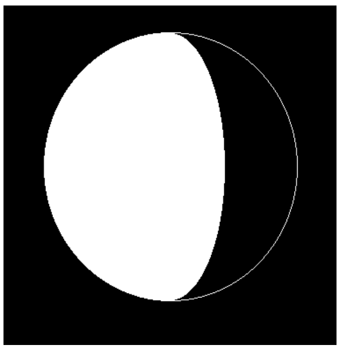
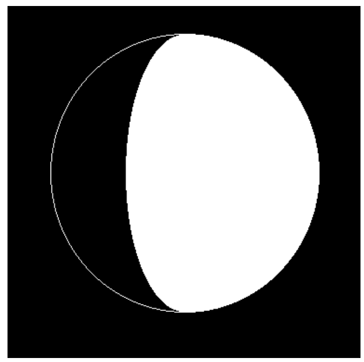


Waning Gibbous



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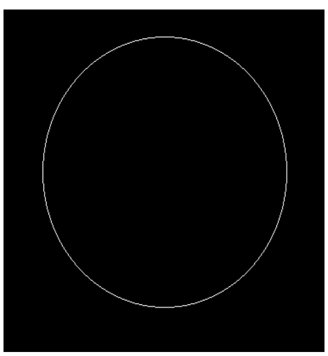
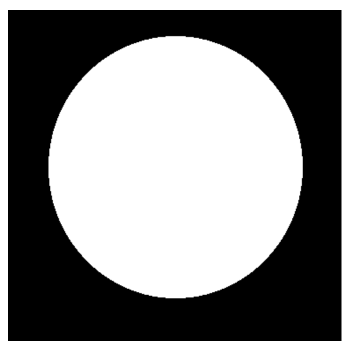
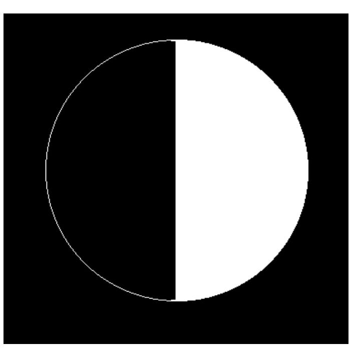


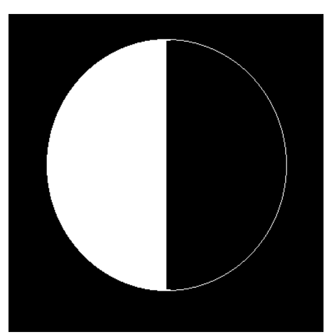
New Moon



Full Moon



First Quarter

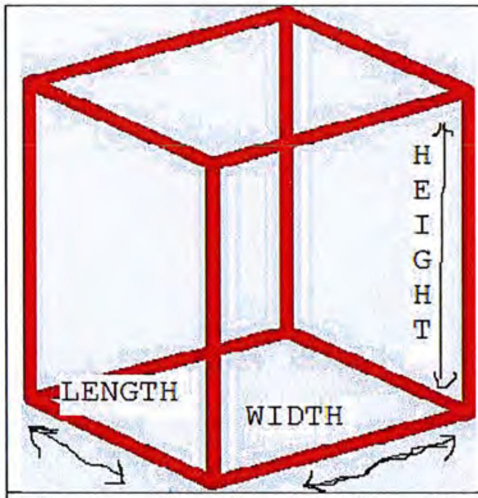


Last Quarter

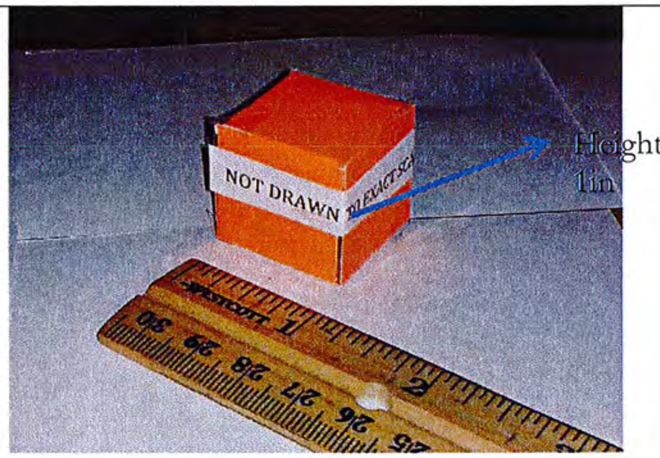
# Surface Area-to-Volume Ratio in a Cell

Cells are limited in how large they can be. This is because the surface area and volume ratio does not stay the same as their size increases. Because of this, it is harder for a large cell to pass materials in and out of the membrane, and to move materials through the cell.

In this activity, you will use cube-shaped models to represent cells. The dimensions along one side will be doubled with each model. You will then use mathematics to calculate the surface area, volume, and the ratio between the two.

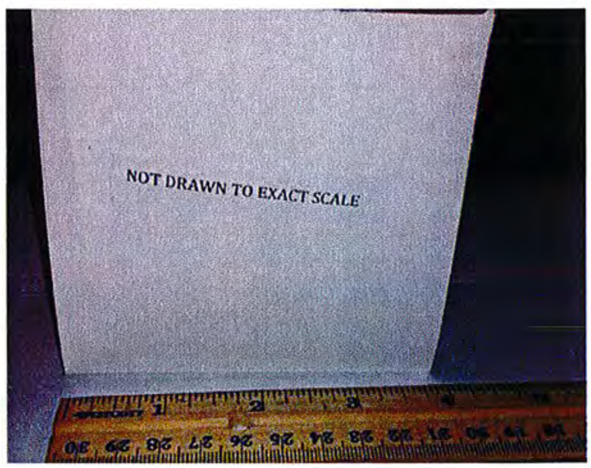



The dimensions (length, width and height) are the same measurement in a cube.




The height of this cube is 1 inch.
What is the width?
What is the length?


Length:
Width:
Height:




Length
Width
Height

Procedure:

1. Record the dimensions in the Data Table (the first one is done for you in the table).

| DATA TABLE: Cell Size Comparison | | | | |
|---|---|---|---|---|
| Cell | Dimensions (in.) | Surface Area ($in^2$) | Volume ($in.^3$) | Ratio Surface area to Volume |
| 1 | 1 x 1 x 1 | | | |
| 2 | | | | |
| 3 | | | | |

**CALCULATIONS:**

| | Formula |
|---|---|
| Surface Area | (Length x width) x 6<br>(6 sides of the cube) |
| Volume | Length x width x height |
| Surface area to volume ratio | <u>Surface area</u><br>Volume<br>(Surface area divided by volume) |

**QUESTIONS:**

1. Which model has the largest surface area?

2. Which model has the largest volume?

3. Which model has the largest ratio?

4. To maintain life, and carry-out cellular functions, materials must be able to move into and out of the cell. Also, material needs to be able to move within the cell. What might be the advantage of having a large surface area?

5. What might be the disadvantage of having a large volume?

## *EQuIP Rubric for Lessons & Units: Science*

**Introduction**

The Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for science provides criteria by which to measure the alignment and overall quality of lessons and units with respect to the Next Generation Science Standards (NGSS). The purpose of the rubric and review process is to: (1) provide constructive criterion-based feedback to developers; (2) review existing instructional materials to determine what revisions are needed; and (3) identify exemplars/models for teachers' use within and across states.

To effectively apply this rubric, an understanding of the National Research Council's *A Framework for K–12 Science Education and the Next Generation Science Standards*, including the NGSS shifts (appendix A of the NGSS), is needed. Unlike the EQuIP Rubrics for mathematics and ELA, there is not a column in the science rubric for shifts. Over the course of the rubric development, writers and reviewers noted that the shifts fit naturally into the other three columns. For example, the blending of the three-dimensions, or three-dimensional learning, is addressed in each of the three columns; coherence and connections to the Common Core State Standards are addressed in the first column; deeper understanding and application of content are addressed in the second column. Each column includes criteria by which to evaluate the integration of engineering, when included in a lesson or unit, through practices or disciplinary core ideas. Another difference between the EQuIP Rubrics from mathematics and ELA is in the name of the columns; the rubric for science refers to them simply as *columns*, whereas the math and ELA rubrics refer to the columns as dimensions. This distinction was made because the Next Generation Science Standards already uses the term *dimensions* to refer to practices, disciplinary core ideas, and crosscutting concepts.

The architecture of the NGSS is significantly different from other sets of standards. The three dimensions, crafted into performance expectations, describe what is to be assessed following instruction and therefore are the measure of proficiency. A lesson or unit may provide opportunities for students to demonstrate performance of practices connected with their understanding of core ideas and crosscutting concepts as foundational pieces. This three-dimensional learning leads toward eventual mastery of performance expectations. In this scenario, quality materials should clearly describe or show how the lesson or unit works coherently with previous and following lessons or units to help build toward eventual mastery of performance expectations. The term *element* is used in the rubric to represent the relevant, bulleted practices, disciplinary core ideas, and crosscutting concepts that are articulated in the foundation boxes of the standards as well as the in the NGSS appendices on each dimension. Given the understanding that a lesson or unit may include the blending of practices, disciplinary core ideas, and crosscutting concepts that are not identical to the combination of practices, disciplinary core ideas, and crosscutting concepts in a performance expectation, the new term *elements* was needed to describe these smaller units of the three dimensions. Although it is unlikely that a single lesson would provide adequate opportunities for a student to demonstrate proficiency on every dimension of a performance expectation, high-quality units are more likely to provide these opportunities to demonstrate proficiency on one or more performances expectations.

There is a recognition among educators that curriculum and instruction will need to shift with the adoption of the NGSS, but there is currently a lack of high-quality, NGSS-aligned materials. The power of the rubric is in the feedback it provides curriculum developers and the productive conversations educators have while evaluating materials (i.e., the review process). For curriculum developers, the rubric and review process provide evidence on the quality and alignment of a lesson or unit to the NGSS. Additionally, the rubric and review process generate feedback on how materials can be further improved and more closely aligned to the NGSS. As more NGSS lessons and units are developed, this rubric may change to meet the evolving needs of supporting both educators in evaluating materials and developers in the modification and creation of materials. Additionally, support materials will be developed to complement the use of this rubric, such as a professional development guide, a criterion discussion guide, and publishers' criteria that will be more focused on textbooks and comprehensive curriculums.

**Directions**

The first step in the review process is to become familiar with the rubric, the lesson or unit, and the practices, disciplinary core ideas, and crosscutting concepts targeted in the lesson or unit. The three columns in the rubric correspond to: alignment to the NGSS, instructional supports, and monitoring student progress. Specific criteria within each column should be considered separately as part of the complete review process and are used to provide sufficient information for determination of overall quality of the lesson or unit.

Also important to the review process is feedback to the developer of the resource. For this purpose a set of response forms is included so that the reviewer can effectively provide criterion-based observations and suggestions for improvement for each column. The response forms correspond to the criteria of the rubric. Evidence for each criterion must be identified and documented and criterion-based feedback should be given to help improve the lesson or unit.

While it is possible for the rubric to be applied by an individual, the quality review process works best with a team of reviewers, as a collaborative process, with the individuals recording their thoughts and then discussing with other team members before finalizing their feedback. Discussions should focus on understanding all reviewers' interpretations of the criteria and the evidence they have found. The goal of the process is to eventually calibrate responses across reviewers and to move toward agreement about quality with respect to the NGSS. Commentary needs to be constructive, with all lessons or units considered "works in progress." Reviewers must be respectful of team members and the resource contributor. Contributors should see the review process as an opportunity to gather feedback rather than to advocate for their work. All observations and suggestions for improvement should be criterion-based and have supporting evidence from the lesson or unit cited.

*Note: This rubric will eventually have scoring guidelines for each column, as well as for an overall rating. However, given the current lack of high quality, NGSS-aligned materials, rather than focusing on ratings at this point in time, the focus should be on becoming familiar with the rubric and using it to provide criterion-based feedback to developers and make revisions to existing materials.*

**Step 1 – Review Materials**

The first step in the review process is to become familiar with the rubric, the lesson or unit, and the practices, disciplinary core ideas, and crosscutting concepts targeted in the lesson or unit.

- Review the rubric and record the grade and title of the lesson or unit on the response form.
- Scan to see what the lesson or unit contains, what practices, disciplinary core ideas, and crosscutting concepts are targeted, and how it is organized.
- Read key materials related to instruction, assessment, and teacher guidance.

**Step 2 – Apply Criteria in Column I: Alignment**

The second step is to evaluate the lesson or unit using the criteria in the first column, first individually and then as a team.

- Closely examine the lesson or unit through the "lens" of each criterion in the first column of the response form.
- Individually check each criterion on the response form for which clear and substantial evidence is found and record the evidence and criterion-based suggestions for specific improvements that might be needed to meet criteria.
- As a team, discuss criteria for which clear and substantial evidence is found, as well as criterion-based suggestions for specific improvements that might be needed to meet criteria.

*If the lesson or unit is not closely aligned to the Next Generation Science Standards, it may not be appropriate to move on to the second and third columns. Professional judgment should be used when weighing the individual criterion. For example, a lesson without crosscutting concepts explicitly called out may be easier to revise than one without appropriate disciplinary core ideas; such a difference may determine whether reviewers believe the lesson merits continued evaluation or not.*

**Step 3 – Apply Criteria in Columns II and III: Instructional Supports and Monitoring Student Progress**

The third step is to evaluate the lesson or unit using the criteria in the second and third columns, first individually and then as a group.

- Closely examine the lesson or unit through the "lens" of each criterion in the second and third columns of the response form.
- Individually check each criterion on the response form for which clear and substantial evidence is found and record the evidence and criterion-based suggestions for specific improvements that might be needed to meet criteria.
- As a team, discuss criteria for which clear and substantial evidence is found, as well as criterion-based suggestions for specific improvements that might be needed to meet criteria.

*When working in a group, teams may choose to compare ratings after each column or delay conversation until each person has rated and recorded input for the two remaining columns. Complete consensus among team members is not required but discussion is a key component of the review process.*

## *EQuIP Rubric for Lessons & Units: Science*

| I. Alignment to the NGSS | II. Instructional Supports | III. Monitoring Student Progress |
|---|---|---|
| The lesson or unit aligns with the conceptual shifts of the NGSS:<br>o Elements of the science and engineering practice(s), disciplinary core idea(s), and crosscutting concept(s), blend and work together to support students in three-dimensional learning to make sense of phenomena or design solutions.<br>  o Provides opportunities to use specific elements of the practice(s) to make sense of phenomena or design solutions.<br>  o Provides opportunities to construct and use specific elements of the disciplinary core idea(s) to make sense of phenomena or design solutions.<br>  o Provides opportunities to construct and use specific elements of the crosscutting concept(s) to make sense of phenomena or design solutions.<br><br>A unit or longer lesson:<br>o Lessons fit together coherently, build on each other, and help students develop proficiency on a targeted set of performance expectations.<br>o Develops connections between different science disciplines by the use of crosscutting concepts and develops connections between different science disciplines by using disciplinary core ideas where appropriate.<br>o Provides grade-appropriate connection(s) to the Common Core State Standards in Mathematics and/or English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects. | The lesson or unit supports instruction and learning for all students:<br>o Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world and that provide students with a purpose (e.g., making sense of phenomena or designing solutions).<br>  o Provides students with multiple phenomena (either firsthand experiences or through representations) that support students in engaging in the practices.<br>  o Engages students in multiple practices that blend and work together with disciplinary core ideas and crosscutting concepts to support students in making sense of phenomena or designing solutions.<br>  o When engineering performance expectations are included, they are used along with disciplinary core ideas from physical, life, or earth and space sciences.<br>o Develops deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts by identifying and building on students' prior knowledge.<br>o Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.<br>o Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and respond to peer and teacher feedback orally and/or in written form as appropriate to support student's three-dimensional learning.<br>o Provides guidance for teachers to support differentiated instruction in the classroom so that every student's needs are addressed by:<br>  o Connecting instruction to the students' home, neighborhood, community and/or culture as appropriate.<br>  o Providing the appropriate reading, writing, listening, and/or speaking modifications (e.g., translations, front loaded vocabulary word lists, picture support, graphic organizers) for students who are English language learners, have special needs, or read well below the grade level.<br>  o Providing extra support for students who are struggling to meet the performance expectations.<br>  o Providing extensions consistent with the learning progression for students with high interest or who have already met the performance expectations.<br><br>A unit or longer lesson:<br>o Provides guidance for teachers throughout the unit for how lessons build on each other to support students developing deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts over the course of the unit. | The lesson or unit supports monitoring student progress:<br>o Assessments are aligned to the three-dimensional learning.<br>o Elicits direct, observable evidence of students' performance of practices connected with their understanding of core ideas and crosscutting concepts.<br>o Formative assessments of three-dimensional learning are embedded throughout the instruction.<br>o Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students.<br>o Assessing student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.<br><br>A unit or longer lesson:<br>o Includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning.<br>o Provides multiple opportunities for students to demonstrate performance of practices connected with their understanding of disciplinary core ideas and crosscutting concepts and receive feedback. |

*EQuIP Rubric for Lessons & Units: Science*

## Response Form

**Reviewer Name or ID:** **Grade:**
**Science Lesson/Unit Title:**

### I. Alignment to the NGSS

The lesson or unit aligns with the conceptual shifts of the NGSS:

| Criteria | Specific evidence from materials under review | Suggestions for improvement |
|---|---|---|
| Elements of the science and engineering practice(s), disciplinary core idea(s), and crosscutting concept(s), blend and work together to support students in three-dimensional learning to make sense of phenomena or design solutions.<br>o Provides opportunities to use specific elements of the practice(s) to make sense of phenomena or design solutions.<br>o Provides opportunities to construct and use specific elements of the disciplinary core idea(s) to make sense of phenomena or design solutions.<br>o Provides opportunities to construct and use specific elements of the crosscutting concept(s) to make sense of phenomena or design solutions. | | |

A unit or longer lesson:

| Criteria | Specific evidence from materials under review | Suggestions for improvement |
|---|---|---|
| Lessons fit together coherently, build on each other, and help students develop proficiency on a targeted set of performance expectations. | | |
| Develops connections between different science disciplines by the use of crosscutting concepts and develops connections between different science disciplines by using disciplinary core ideas where appropriate. | | |
| Provides grade-appropriate connection(s) to the Common Core State Standards in Mathematics and/or English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects. | | |

## II. Instructional Supports

The lesson or unit supports instruction and learning for all students:

| Criteria | Specific evidence from materials under review | Suggestions for improvement |
|---|---|---|
| Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world and that provide students with a purpose (e.g., making sense of phenomena or designing solutions).<br>o Provides students with multiple phenomena (either firsthand experiences or through representations) that support students in engaging in the practices.<br>o Engages students in multiple practices that blend and work together with disciplinary core ideas and crosscutting concepts to support students in making sense of phenomena or designing solutions.<br>o When engineering performance expectations are included, they are used along with disciplinary core ideas from physical, life, or earth and space sciences. | | |
| Develops deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts by identifying and building on students' prior knowledge. | | |
| Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning. | | |
| Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and respond to peer and teacher feedback orally and/or in written form as appropriate to support student's three-dimensional learning. | | |
| Provides guidance for teachers to support differentiated instruction in the classroom so that every student's needs are addressed by:<br>o Connecting instruction to the students' home, neighborhood, community and/or culture as appropriate.<br>o Providing the appropriate reading, writing, listening, and/or speaking modifications (e.g., translations, front loaded vocabulary word lists, picture support, graphic organizers) for students who are English language learners, have special needs, or read well below the grade level.<br>o Providing extra support for students who are struggling to meet the performance expectations.<br>o Providing extensions consistent with the learning progression for students with high interest or who have already met the performance expectations. | | |

A unit or longer lesson:

| Criteria | Specific evidence from materials under review | Suggestions for improvement |
|---|---|---|
| Provides guidance for teachers throughout the unit for how lessons build on each other to support students developing deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts over the course of the unit. | | |

## III. Monitoring Student Progress

The lesson or unit supports monitoring student progress:

| Criteria | Specific evidence from materials under review | Suggestions for improvement |
|---|---|---|
| Assessments are aligned to the three-dimensional learning. | | |
| Elicits direct, observable evidence of students' performance of practices connected with their understanding of core ideas and crosscutting concepts. | | |
| Formative assessments of three-dimensional learning are embedded throughout the instruction. | | |
| Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students. | | |
| Assessing student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students. | | |

A unit or longer lesson:

| Criteria | Specific evidence from materials under review | Suggestions for improvement |
|---|---|---|
| Includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning. | | |
| Provides multiple opportunities for students to demonstrate performance of practices connected with their understanding of disciplinary core ideas and crosscutting concepts and receive feedback. | | |