Smithsonian

STC

SCIENCE AND TECHNOLOGY CONCEPTS™
MIDDLE SCHOOL

IGNITE THEIR POTENTIAL!

ALL NEW! NGSS
Middle School Science
from the Smithsonian

CAROLINA®
www.carolina.com

9 All-New Units for Middle School from the Smithsonian!

Smithsonian's STCMS Is Built to Meet the Next Generation Science Standards and Incorporate the 5 Innovations

- **Three-dimensional learning** construction—every lesson, every unit
- Lessons that apply **science concepts** to NGSS* **engineering design**
- Hands-on investigations in which students build explanations for real-world **phenomena and design solutions—everyday**
- **Coherent learning progression** that develops lesson by lesson, unit by unit—no "random acts of science"
- **Literacy and mathematics connections** that bridge science content and lead to deep understanding

STCMS Learning Framework

Physical Science	Life Science	Earth/Space Science
Energy, Forces, and Motion	Ecosystems and Their Interactions	Weather and Climate Systems
Matter and Its Interactions	Structure and Function	Earth's Dynamic Systems
Electricity, Waves, and Information Transfer	Genes and Molecular Machines	Space Systems Exploration

Hands Down, Research Tells Us that Inquiry-Based Instruction Is Best for Your Students

Choose instruction that has been proven to improve student performance and test scores not only in science, but also in reading and math.

What students say about STC:
"In science you do hands-on activities instead of just writing and doing notes, and you get to work with people. For visual people in science that's a lot better because you get to see the experience and experiment."

What administrators say about STC:
"We saw instant results in our test scores—a double-digit increase in our end-of-grade state performance..."

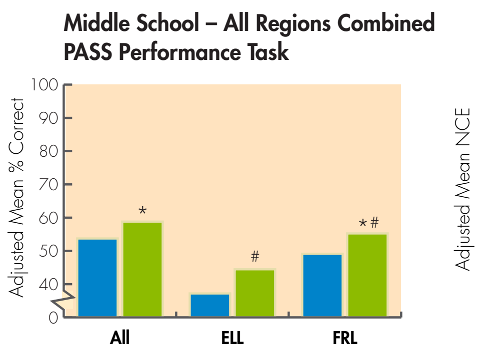
* Next Generation Science Standards is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards was involved in the production of, and does not endorse, this product.

STC—Proven to Raise Test Scores in Science, Reading, and Math

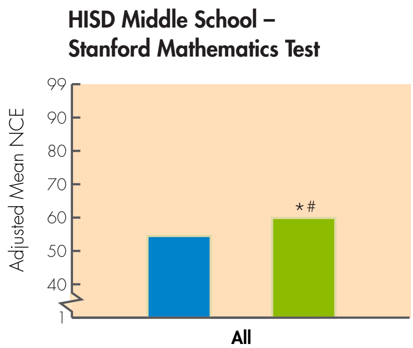
In a 5-year randomized control trial with 60,000 students, reading, math, and science test scores increased for ALL students.

The LASER group using STC showed statistically significant and educationally meaningful test results ***even in the middle school years where test-score increases are a challenge!***

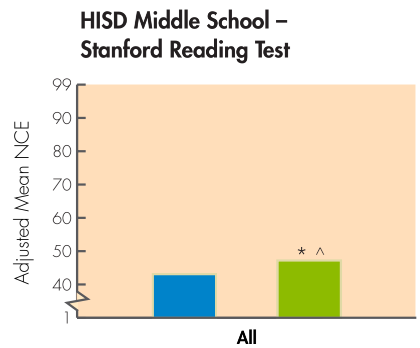
Science Scores Increased



Math Scores Increased



Reading Scores Increased



* statistically significant results # educationally meaningful results

LASER group Comparison group

Find out more. Download the complete LASER i3 results: https://ssec.si.edu/our-results

Everything You Need—Print, Digital, and Lab Materials—In One Package

Each STCMS unit features:

- Teacher Edition (print and digital) that includes an assessment system designed for three-dimensional learning and support for educators transitioning to NGSS
- Access to Carolina Science Online®
  - Teacher Edition eBook Access
  - Student Guide eBook Access
  - Student Resources in English and Spanish
- 16 Hardbound Student Guides
- Hands-On Materials Kit of Choice
  - 5-Class Kit (enough materials for up to 160 students)
  - 1-Class Kit (enough materials for up to 32 students)

Three-Dimensional Learning—The Signature Innovation of the Next Generation Science Standards

STCMS provides teacher support in weaving together Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts to address Performance Expectations over time.

Lesson 5 Kinetic and Potential Energy

Alignment to Next Generation Science Standards

- **MS-PS3-1:** Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
- **MS-PS3-2:** Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
- **MS-PS3-5:** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Investigation 5.2 addresses the NGSS **performance expectation MS-PS3-1** as students **describe the relationships** of kinetic energy to the mass of an object and to the speed of an object and **construct and interpret graphical displays of data**.

Both Investigations 5.1 and 5.2 address NGSS **performance expectation MS-PS3-2** because students need to **plan and develop a model** to describe when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. In addition, these investigations support NGSS **performance expectation MS-PS3-5** in that **students must account for how kinetic energy increases and then decreases during their investigation**. In both investigations, potential energy is transformed into kinetic energy and is then transferred to the sand when the ball comes to a stop.

Investigations 5.1 and 5.2 align to the **science and engineering practices of developing and using models and planning and carrying out investigations** because students are responsible for developing their plan, using a model, and then carrying out the investigations. During data analysis, students see that **scientific knowledge is based on empirical evidence**. After both investigations, students **evaluate and communicate their derived information**. Also, for both investigations, students were involved in **constructing explanations and designing solutions**. The models they developed were in response to **designing a solution** that would **explain the relationship** between mass and weight and model gravitational potential and kinetic energies, respectively.

Investigations 5.1 and 5.2 also support the **crosscutting concepts of cause and effect** as students observe changes in mass affect weight, gravitational potential, and kinetic energies. They construct and observe **systems and system models**. Students use their models to demonstrate **stability and change**. With the support of Building Your Knowledge readings and Reflecting On What You've Done activities, students understand that matter has energy and changes to matter (in terms of position and mass) can affect stability and types of energy.

Complete Three-Dimensional Learning Support

Every lesson begins with the Alignment to Next Generation Science Standards. This alignment shows exactly where the:

- Performance Expectations are supported
- Crosscutting Concepts are supported
- Science and Engineering Practices are supported

What Three-Dimensional Learning Looks Like in STCMS

Lessons that ignite learning through phenomena

Lesson 5

Kinetic and Potential Energy

FOCUS QUESTION How can gravity affect the motion of objects on Earth?

Introduction

Imagine you are going to jump into a swimming pool from a diving board. Does the height of the diving board matter? Will the water feel different on your feet if you jump from the 1-meter springboard or the 3-meter springboard? How about from a 10-meter platform? The higher you are when you begin your jump, the more energy you will have when you hit the water. In this lesson, you will explore how height, mass, and energy are related to motion.

Objectives for This Lesson

- Differentiate between potential energy and kinetic energy.
- Construct a graph to describe the relationship between the mass or height of a ball and the size of the impression it creates.
- Describe how the mass or height of an object relates to potential or kinetic energy.
- Develop a model to describe the gravitational potential energy of a system.
- Use experimental evidence to support the claim that an energy transfer is responsible for changes in kinetic energy.

Figure 5.1

From which locations in the picture could this boy jump to be associated with more energy, less energy, or the same energy when he hits the water?

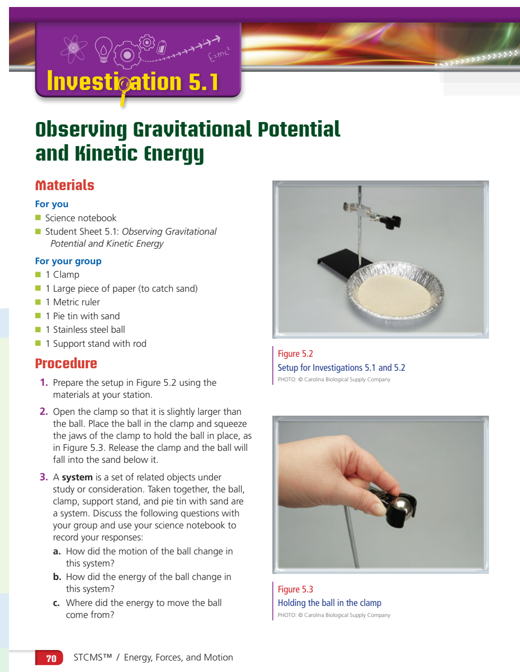
PHOTO: FamVeld/Shutterstock.com

64 STCMS™ / Energy, Forces, and Motion

FOCUS QUESTION Questions phenomena like scientists do.

Introduction

Phenomena is presented in a real-world context, connecting to students' lives.



Investigation 5.1

Observing Gravitational Potential and Kinetic Energy

Materials

For you

- Science notebook
- Student Sheet 5.1: *Observing Gravitational Potential and Kinetic Energy*

For your group

- 1 Clamp
- 1 Large piece of paper (to catch sand)
- 1 Metric ruler
- 1 Pie tin with sand
- 1 Stainless steel ball
- 1 Support stand with rod

Procedure

1. Prepare the setup in Figure 5.2 using the materials at your station.
2. Open the clamp so that it is slightly larger than the ball. Place the ball in the clamp and squeeze the jaws of the clamp to hold the ball in place, as in Figure 5.3. Release the clamp and the ball will fall into the sand below it.
3. A **system** is a set of related objects under study or consideration. Taken together, the ball, clamp, support stand, and pie tin with sand are a system. Discuss the following questions with your group and use your science notebook to record your responses:
   a. How did the motion of the ball change in this system?
   b. How did the energy of the ball change in this system?
   c. Where did the energy to move the ball come from?

Figure 5.2

Setup for Investigations 5.1 and 5.2

PHOTO: © Carolina Biological Supply Company

Figure 5.3

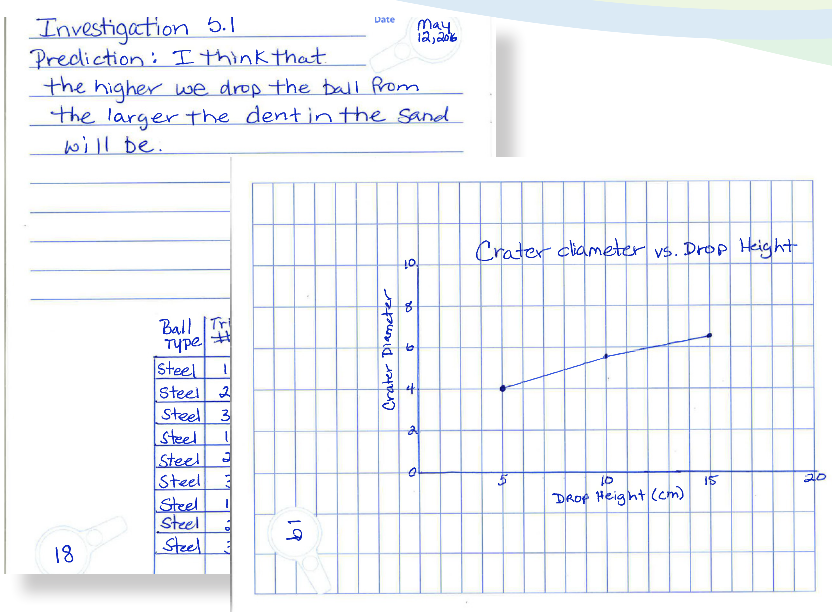
Holding the ball in the clamp

PHOTO: © Carolina Biological Supply Company

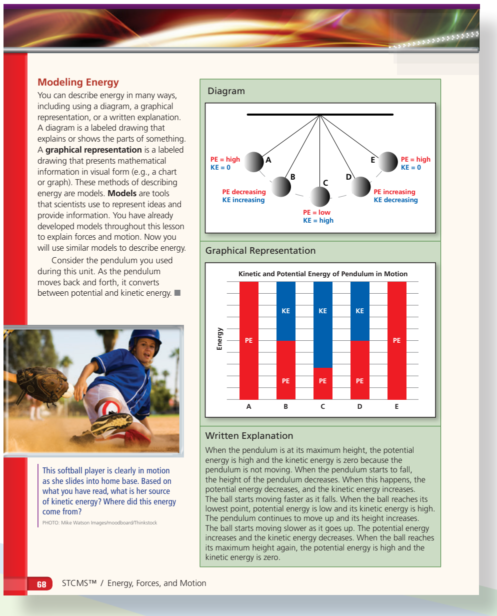
70 STCMS™ / Energy, Forces, and Motion

Lessons that explore phenomena through experiential learning

- Students build systems and plan and carry out investigations that mimic and generate data about science phenomena.



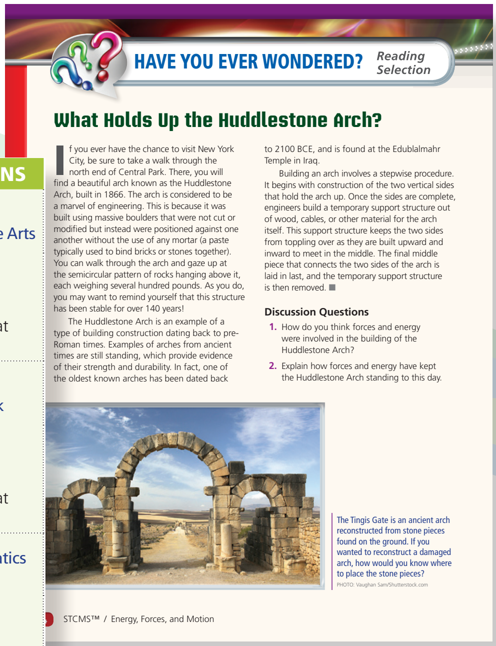
- Students gather data that serves as evidence to provide explanations for phenomena.
- Students use data collection to generate additional questions or problems.
- Students analyze and interpret data to aid in revealing patterns and relationships, to create explanations, or to inform design solutions.



Lessons that use models to

- represent systems
- develop questions and explanations
- generate data
- communicate ideas

Lessons that integrate literacy and math to support three-dimensional learning



CONNECTIONS

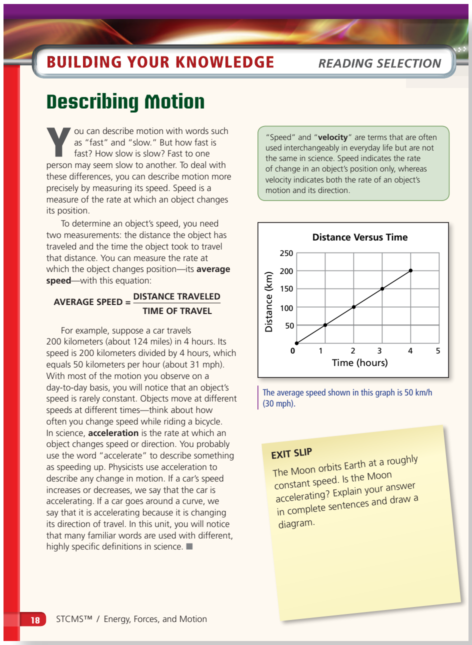
English Language Arts
Getting Started
Investigation 5.1
Investigation 5.2
Reflecting On What You've Done

Science Notebook
Getting Started
Investigation 5.1
Investigation 5.2
Reflecting On What You've Done

Mathematics
Getting Started
Investigation 5.1
Investigation 5.2
Reflecting On What You've Done

Literacy integration develops deep understanding, creating connections between science and the real world.

- Discussion questions check student understanding of a reading passage and incorporate their understanding of Practices and Crosscutting Concepts.
- Reading selections connect science and the real world.
- Discussion questions directly support ELA Standards.



Math integration allows students to learn to quantitatively describe and measure objects, events, and processes.

Lessons that convert learning experiences into understanding of phenomena

Reflecting On What You've Done asks students to think about and apply concepts they have explored in new contexts, deepening their understanding.

1. Read Extending Your Knowledge: *It Is Official: Water Towers Are Cool* and answer the questions that follow the reading in your science notebook.
2. Develop a model that describes the energy of a book falling toward the ground. In your model, include a diagram, a graphical representation, and a written explanation.
3. Given what you have learned from the investigation, design a safe system for arranging various items in a bookshelf. Explain how you applied the concept of gravitational potential energy in your design.

EXIT SLIP

How can gravity affect the motion of objects on Earth?

Exit Slips gauge student understanding of phenomena and serve as valuable formative assessments for both teachers and students.

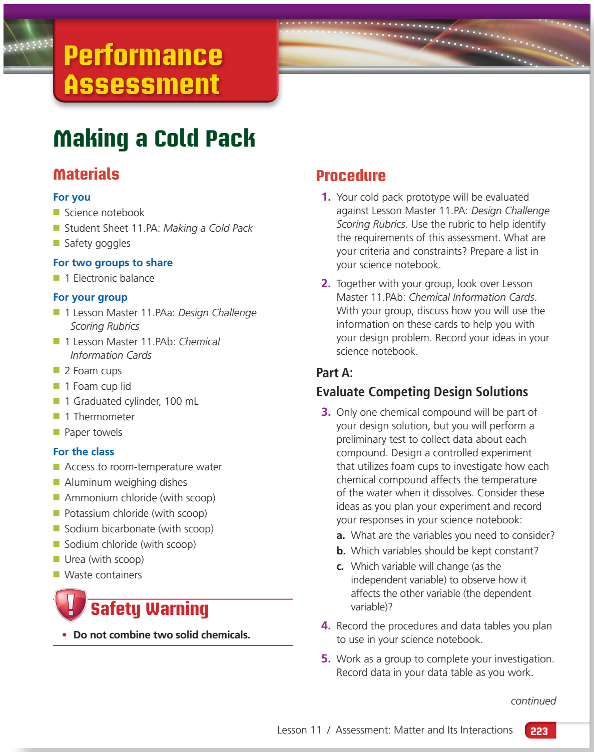
74 STCMS™ / Energy, Forces, and Motion

STCMS Applies Science Concepts to NGSS Engineering Design

Students directly engage in structural, mechanical, chemical, and biological engineering design challenges throughout each unit using the science content knowledge obtained during the unit lessons.

Designing a Cold Pack

What happens when you twist an ankle or sprain a wrist during sports practice or gym class or playing around with friends? A cold pack comes to the rescue! A plastic bag filled with a mystery substance that, when agitated, magically becomes cold. But it's not magic, it's science! And engineering! Students explain this "magic" by applying what they've learned to a design challenge in the unit assessment in *Matter and Its Interactions*.



Performance Assessment

Making a Cold Pack

Materials

For you
- Science notebook
- Student Sheet 11.PA: *Making a Cold Pack*
- Safety goggles

For two groups to share
- 1 Electronic balance

For your group
- 1 Lesson Master 11.PAa: *Design Challenge Scoring Rubrics*
- 1 Lesson Master 11.PAb: *Chemical Information Cards*
- 2 Foam cups
- 1 Foam cup lid
- 1 Graduated cylinder, 100 mL
- 1 Thermometer
- Paper towels

For the class
- Access to room-temperature water
- Aluminum weighing dishes
- Ammonium chloride (with scoop)
- Potassium chloride (with scoop)
- Sodium bicarbonate (with scoop)
- Sodium chloride (with scoop)
- Urea (with scoop)
- Waste containers

Safety Warning
- Do not combine two solid chemicals.

Procedure

1. Your cold pack prototype will be evaluated against Lesson Master 11.PA: *Design Challenge Scoring Rubrics*. Use the rubric to help identify the requirements of this assessment. What are your criteria and constraints? Prepare a list in your science notebook.
2. Together with your group, look over Lesson Master 11.PAb: *Chemical Information Cards*. With your group, discuss how you will use the information on these cards to help you with your design problem. Record your ideas in your science notebook.

Part A:
Evaluate Competing Design Solutions

3. Only one chemical compound will be part of your design solution, but you will perform a preliminary test to collect data about each compound. Design a controlled experiment that utilizes foam cups to investigate how each chemical compound affects the temperature of the water when it dissolves. Consider these ideas as you plan your experiment and record your responses in your science notebook:
   a. What are the variables you need to consider?
   b. Which variables should be kept constant?
   c. Which variable will change (as the independent variable) to observe how it affects the other variable (the dependent variable)?
4. Record the procedures and data tables you plan to use in your science notebook.
5. Work as a group to complete your investigation. Record data in your data table as you work.

continued

Lesson 11 / Assessment: Matter and Its Interactions 223

Becoming Aware of Real-World Phenomena through Engineering Design

Phenomena is all around us—even in the cold pack that helps an injured wrist or ankle feel better. Challenge students to take the mystery out of this phenomenon by using the knowledge they've gained throughout the unit to design a cold pack for a manufacturing company.

In this investigation, student groups:

- plan and carry out an investigation to test different compounds to determine their suitability for a new cold pack design;
- evaluate that design using a student-generated list of criteria and constraints;
- gather and analyze the data from their investigation; and
- use this information to inform their decisions about optimizing their final design solution for a cold pack.

STCMS Incorporates Engineering Design Challenges throughout Every Unit!

Examples of Engaging Engineering Challenges in STCMS:

Energy, Forces, and Motion: Learning about the science behind energy, forces, and motion, students engineer a balloon rocket, redesign a roller coaster, and find a way to keep bananas off the street!

Weather and Climate Systems: Using their knowledge of hurricanes and where they occur, students sketch a detailed design of a storm-resistant building and present their designs to their peers.

Electricity, Waves, and Information Transfer: Students apply what they have learned throughout the unit to design, build, and test prototypes of technological systems that utilize electricity and waves to communicate information.

Ecosystems and their Interactions: Students consider constraints and criteria for designing a habitat for an organism in captivity.

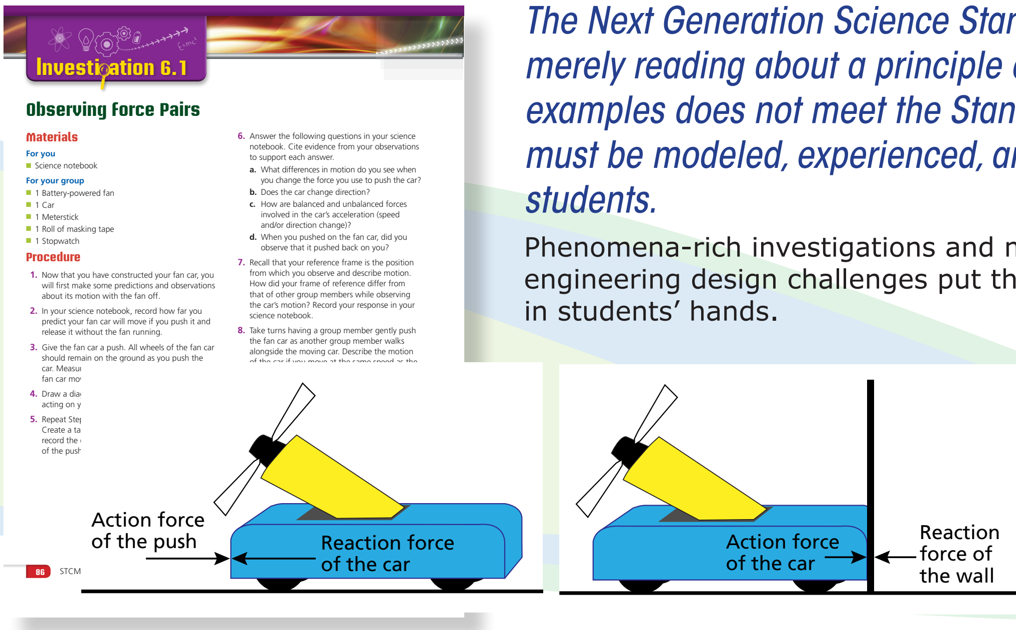
Smithsonian's STCMS lays the foundation for science and engineering in middle school and beyond.

STEM starts here!

STCMS Puts Real-World and Experiential Phenomena in Students' Hands—Every Day

"Phenomena" appears in the Middle School Next Generation Science Standards 40 times!

Phenomena is a big part of the new standards and is the link between all three dimensions of the NGSS. The connection of phenomena to science provides concrete experiences that ignite students' interest in learning more.



The Next Generation Science Standards are clear: merely reading about a principle and some examples does not meet the Standards. Phenomena must be modeled, experienced, and explained by students.

Phenomena-rich investigations and meaningful engineering design challenges put the experience in students' hands.

Hands-on Phenomena Ignites Interest in Non-Fiction Reading

Non-fiction literacy supports phenomena by providing real-world, contextually relevant connections to science content and sparks student interest.

STCMS Engages Students with Phenomena that Integrates Science Disciplines of NGSS

Examples of Engaging Phenomena in STCMS:

Energy, Forces, and Motion: Students explore the phenomena of the energy of motion through the real-world contexts of roller coasters and balloon rockets.

Ecosystems and Their Interactions: Students explore the phenomena of energy flow through ecosystems through the real-world contexts of pond sustainability and population homeostasis.

Earth's Dynamic Systems: Students explore the phenomenon of the cycling of matter and energy that drives the cycling of Earth's materials through the real-world contexts of modeling the rock cycle and the role of heat and pressure.

Smithsonian's STCMS:

- Focuses on phenomena
- Supports phenomena with hands-on investigations
- Incorporates classroom discourse to ensure understanding
- Enriches phenomena with non-fiction literacy

Exploring Phenomena—Every Unit. Every Lesson.

The STCMS Assessment System—Catch Misconceptions Early

STCMS provides NGSS rubrics for every unit!

STCMS provides powerful assessment every step of the way

A good assessment system positions students for success on any external assessment that is well-aligned to NGSS standards. **A great assessment system goes beyond** to provide a coherent system of classroom-based assessments that provide powerful information to inform teaching and learning for not only the teacher, but the student as well.

The Smithsonian's STCMS assessment system includes:

- Pre-assessment
- Multiple forms of formative assessment, including Exit Slips
- Powerful self-assessment for students
- Summative assessment—performance and written components targeting the full range of the unit's concepts and practices
- Unit-specific rubrics to assess three-dimensional learning

An Assessment System that Informs Your Instruction

What do they already know?

Each STCMS unit begins with a **pre-assessment** lesson designed to:

- reveal misconceptions and preconceptions
- assist in lesson planning
- serve as a gauge of students' prior knowledge of key disciplinary core ideas, crosscutting concepts, and science and engineering practices.

What did they learn today?

STCMS **formative assessment** informs instruction through:

- Exit Slips that gauge student understanding through writing, technical drawing, and claims and evidence reasoning based on the day's work
- Self-Assessment that prompt awareness and help students think of ways to improve their learning strategies
- Reflecting on What You've Done, which allows students to see for themselves how well they can explain lesson phenomena

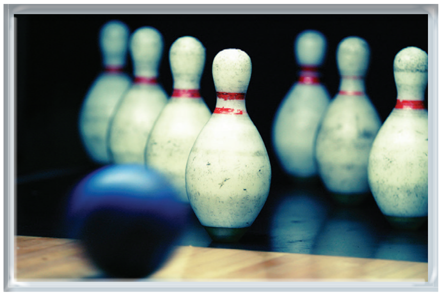


Figure 4.4
Imagine what might happen when the ball hits the bowling pins.
PHOTO: proactions/iStock/Thinkstock

EXIT SLIP

In bowling, a strike is when a bowler knocks down all of the pins. Using Newton's first and second laws of motion, describe some of the choices a bowler must make to maximize their chances of a strike. Include a force diagram showing the forces at play when the ball first contacts the central pin.

Performance Assessment

Improving Produce Transportation

Materials

For you
- Science notebook
- Safety goggles

For your group*
- 1 Lesson Master 9.PA: *Design Challenge Scoring Rubrics*
- 4 Large washers
- 1 Car with rubber stopper
- 1 Car with rubber stopper and metal ring
- 1 Clamp
- 1 Clamp pulley
- 1 Cup with plastic fruit
- 1 Inclined plane
- 1 Meterstick
- 1 Metric ruler
- 1 Paper clip
- 1 Piece of string
- 1 Roll of masking tape
- 1 Support stand with rod

*Other materials may be available for the Performance Assessment. Consult with your teacher.

Procedure

1. Without making any modifications to the car, fill it with as many pieces of fruit as possible. Draw a sketch of the car, and record the number and type of fruit used to fill the car.
2. Use your understanding of energy, forces, and motion to predict what specifically will happen to the fruit when the car does the following:
   a. Travels up a ramp
   b. Has a sudden change in velocity
   c. Has a collision with another car
3. Plan an investigation to test your predictions.

144 STCMS™ / Energy, Forces, and Motion

Lesson Master 9.PA: Design Challenge Scoring Rubrics

Produce Transport				
Criterion	**1. Beginning**	**2. Developing**	**3. Proficient**	**4. Exemplary**
Performance of Design Challenge Task	Group modified produce, or design transported 10 pieces of fruit or fewer.	Group design transported greater than 10 pieces of fruit.	Group design transported greater than 15 pieces of fruit.	Group design transported greater than 20 pieces of fruit.
Creativity	Group used the prototype with no modifications.	Group used the prototype with only minor modifications.	Group used the prototype with significant modifications.	Group used the prototype with modifications that utilized a novel approach or unique materials.

Grading Rubric				
Criterion	**1. Beginning**	**2. Developing**	**3. Proficient**	**4. Exemplary**
Written Instructions and Schematics	Group did not present written instructions or schematics pertaining to the design challenge.	Group presented either written instructions or schematics that were unclear or incomplete but pertained to the design challenge.	Group presented either written instructions or schematics that were clear and pertained to the design challenge.	Group presented written instructions and schematics that were clear, detailed, and pertained to the design challenge.
Design Implementation	Group constructed a model that did not pertain to the design challenge.	Group constructed a model that somewhat pertained to the design challenge.	Group constructed a model that met the criteria of the design challenge.	Group constructed a model that exceeded the criteria of the design challenge.
Testing and Data Collection	Group did not test their design.	Group did not use appropriate procedures to test their design and did not collect relevant data.	Group used appropriate procedures to test their design but did not collect relevant data.	Group used appropriate procedures to test their design and collected relevant data.
Reflection and Presentation	Group presented methods and results in an incomplete and unclear manner and did not reflect on choices.	Group presented methods or results in an unclear manner or did not reflect on choices based on scientific principles.	Group presented methods or results adequately. Group reflected on choices based on scientific principles most of the time.	Group presented methods or results clearly and accurately. Group always reflected on choices based on scientific principles.

© Smithsonian Institution

STCMS™ / Energy, Forces, and Motion   Lesson 9 / Assessment: Energy, Forces, and Motion

What did they learn over the course of the unit?

Each unit concludes with a **summative assessment** that targets the full range of unit concepts and practices through:

- a performance task investigation
- a written assessment consisting of multiple-choice and constructed-response questions
- a unit-specific rubric that evaluates and tracks individual student progress

Appendix D: Assessing Three-Dimensional Learning

Science and Engineering P...

Criterion | 1. Begin...

Asking Questions and Defining Problems

Developing and Using Models

Planning and Carrying Out Investigations

8 STCMS™ / Energy, Forces, a...

Appendix D: Assessing Three-Dimensional Learning

Crosscutting Concept...

Criterion | 1. ...

Cause and Effect

Scale, Proportion, and Quantity

Systems and System Models

Energy and Matter

Stability and Change

Appendix D: Assessing Three-Dimensional Learning

Disciplinary Core Ideas			
Criterion	**1. Beginning**	**2. Developing**	**3. Proficient**
PS2.B: Forces and Motion	Student cannot explain that magnetic forces can be attractive and repulsive.	Student can partially explain that magnetic forces can be attractive and repulsive.	Student can explain that magnetic forces can be attractive and repulsive.
	Student cannot explain that magnetic forces and their sizes depend on the magnetic strengths involved and the distances between interacting objects.	Student can partially explain that magnetic forces and their sizes depend on the magnetic strengths involved and the distances between interacting objects.	Student can explain that magnetic forces and their sizes depend on the magnetic strengths involved and the distances between interacting objects.
	Student cannot explain that gravitational forces are always attractive.	Student can partially explain that gravitational forces are always attractive.	Student can partially explain gravitational forces are always attractive.
	Student cannot explain that there is a gravitational force between any two masses.	Student can partially explain that there is a gravitational force between any two masses.	Student can explain that there is a gravitational force between any two masses.
	Student cannot explain that the gravitational force between two objects is very small, except when one or both of the objects has a large mass.	Student can partially explain that the gravitational force between two objects is very small, except when one or both of the objects has a large mass.	Student can explain that the gravitational force between two objects is very small, except when one or both of the objects has a large mass.
	Student cannot explain that forces that act at a distance can be explained by fields that extend through space and can be mapped by their effect on a test object.	Student can partially explain that forces that act at a distance can be explained by fields that extend through space and can be mapped by their effect on a test object.	Student can explain that forces that act at a distance can be explained by fields that extend through space and can be mapped by their effect on a test object.

12 STCMS™ / Energy, Forces, and Motion

How are they progressing against the Next Generation Science Standards?

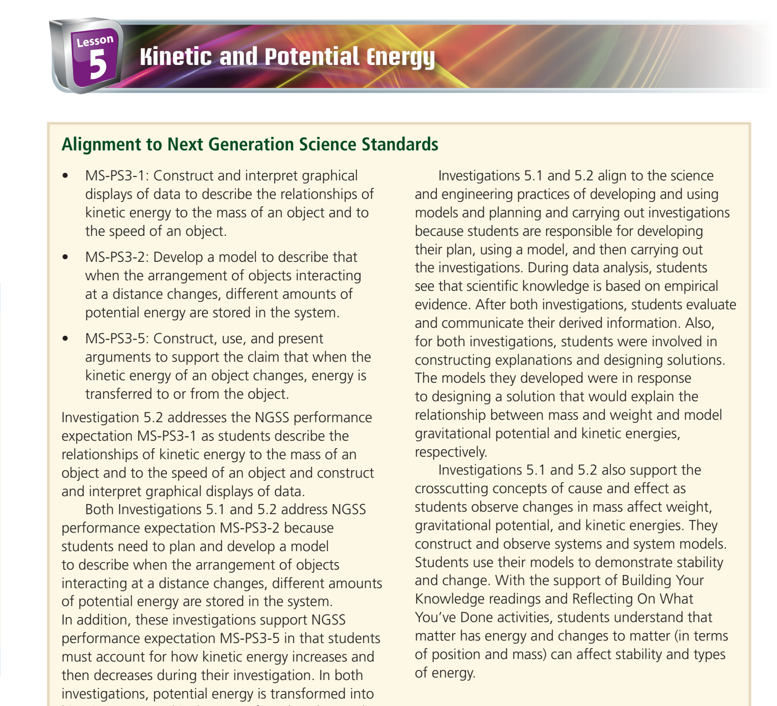
Unit-specific rubrics to assess **three-dimensional learning** guide evaluation of student proficiency with the Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas addressed in the specific unit.

With Smithsonian's STCMS, students will be ready for the high-stakes challenges of high school and beyond!

Support for Teachers During the Transition to NGSS

Three-dimensional learning calls for building to Performance Expectations over time with Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas.

Your STCMS Teacher Edition has the explanations you need!



Lesson 5 Kinetic and Potential Energy

Alignment to Next Generation Science Standards

- MS-PS3-1: Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
- MS-PS3-2: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
- MS-PS3-5: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Investigation 5.2 addresses the NGSS performance expectation MS-PS3-1 as students describe the relationships of kinetic energy to the mass of an object and to the speed of an object and construct and interpret graphical displays of data.

Both Investigations 5.1 and 5.2 address NGSS performance expectation MS-PS3-2 because students need to plan and develop a model to describe when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. In addition, these investigations support NGSS performance expectation MS-PS3-5 in that students must account for how kinetic energy increases and then decreases during their investigation. In both investigations, potential energy is transformed into

Investigations 5.1 and 5.2 align to the science and engineering practices of developing and using models and planning and carrying out investigations because students are responsible for developing their plan, using a model, and then carrying out the investigations. During data analysis, students see that scientific knowledge is based on empirical evidence. After both investigations, students evaluate and communicate their derived information. Also, for both investigations, students were involved in constructing explanations and designing solutions. The models they developed were in response to designing a solution that would explain the relationship between mass and weight and model gravitational potential and kinetic energies, respectively.

Investigations 5.1 and 5.2 also support the crosscutting concepts of cause and effect as students observe changes in mass affect weight, gravitational potential, and kinetic energies. They construct and observe systems and system models. Students use their models to demonstrate stability and change. With the support of Building Your Knowledge readings and Reflecting On What You've Done activities, students understand that matter has energy and changes to matter (in terms of position and mass) can affect stability and types of energy.

Lesson-specific alignment to the NGSS makes it clear how each part of the standards is tackled, ensuring true three-dimensional learning.

Meeting Standards with STCMS™

Meeting Next Generation Science Standards with STCMS

The STCMS Program is based on the guidelines set forth in the Next Generation Science Standards (NGSS). The NGSS, finalized in April 2013, were developed by a core team of U.S. states in collaboration with various stakeholders in science, science education, higher education, and industry, under the management of Achieve. The foundation for the NGSS was the National Research Council (NRC) report, "A Framework for K–12 Science Education," which identified the knowledge and skills students need to be proficient in science. The National Science Teachers Association and American Association for the Advancement of Science were also instrumental in the NGSS development process.

The standards in the NGSS are presented as performance expectations (PEs) that outline what students should know and be able to do from kindergarten through twelfth grade in four scientific domains: life science, physical science, and Earth and space science, as well as areas of interdependence: engineering, technology, and the applications of science. Each PE in the NGSS comprises components of the three dimensions outlined in the NRC Framework: disciplinary core ideas, crosscutting concepts, and science and engineering practices.

Disciplinary Core Ideas

According to the NRC Framework (p. 31), disciplinary core ideas in each of the four domains were identified as such based on their alignment with at least two of four criteria. The idea should:

- have broad importance across multiple sciences or engineering disciplines or be a key organizing concept of a single discipline,
- provide a key tool for understanding or investigating more complex ideas and solving problems,
- relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge, and
- be teachable and learnable over multiple grades at increasing levels of depth and sophistication.

The Framework recognizes the value of teaching a limited number of concepts in greater depth, rather than a greater diversity of concepts in limited depth. The end goal of identifying disciplinary core ideas is to "prepare students with sufficient core knowledge so they can . . . evaluate and select reliable sources of scientific information" on their own later (NRC, 2012, p. 31).

Core idea learning progressions in the Framework are organized by grade band endpoints at grades 2, 5, 8, and 12; thus, the NGSS identify the knowledge that students should demonstrate by the end of second grade, and elementary, middle, and secondary schools.

16 Tab 3 / Meeting Standards with STCMS™

STCMS provides educators with support for this new innovation in teaching every step of the way.

Teacher support that helps you and helps you support your students

- **Common Misconceptions** identifies ideas your students may already have and helps you guide them through conceptual change.
- **Background** provides teachers, who may not have recent experience with the content, with foundational knowledge about lesson topics
- **Built-in professional development** for teachers supports the transition to NGSS

NGSS, English Language Arts, and Math Standards: Easily Identifiable, Lesson by Lesson

Lesson at a Glance provides an overview of each lesson, including the lesson-specific NGSS correlation and connections to English Language Arts and Math Standards.

Lesson 5 **Kinetic and Potential Energy** — LESSON AT A GLANCE

	GETTING STARTED	INVESTIGATION 5.1: *Observing Gravitational Potential and Kinetic Energy*	INVESTIGATION 5.2: *Analyzing Potential and Kinetic Energy*	REFLECTING ON WHAT YOU'VE DONE	*EXTENDING YOUR KNOWLEDGE* READING SELECTIONS
Overview	• Students read Building Your Knowledge: *Potential and Kinetic Energy*, which discusses potential energy and how it changes when an object changes height above the ground. • Students differentiate between potential and kinetic energy. • Students read Building Your Knowledge: *Gravitational Potential Energy* and discuss how it can be increased or decreased.	• Students predict how the height of a ball affects gravitational potential energy and plan an investigation to evaluate their prediction. • Students plan an investigation to model and change the gravitational potential energy of a system.	• Students read Building Your Knowledge: *Energy of Motion*, which describes kinetic energy and its relationship to mass. • Students predict how the mass of a ball affects gravitational potential energy and plan an investigation to evaluate their prediction. • Students plan how to model and change the kinetic energy of a system.	• Students discuss and answer questions about the investigations. • Students develop a system for organizing a bookshelf based on gravitational potential energy.	• *It Is Official: Water Towers Are Cool* describes how potential energy is used to maintain water pressure. • *Energy Forms* describes different forms of energy (chemical, elastic, electrical, electromagnetic, magnetic, mechanical, nuclear, and thermal).
Objectives	• Differentiate between potential energy and kinetic energy.	• Construct a graph to describe the relationship between the height of a ball and its energy. • Describe how the height of an object relates to potential energy. • Develop a model to describe the gravitational potential energy of a system.	• Construct a graph to describe the relationship between the mass of a ball and the size of the impression it creates. • Describe how the mass of an object relates to potential and kinetic energy. • Develop a model to describe the gravitational potential energy of a system.	• Students discuss and answer questions about the investigations. • Use experimental evidence to support the claim that an energy transfer is responsible for changes in kinetic energy. • Students apply what they have learned about potential and kinetic energy to a real-world situation.	• ***It Is Official: Water Towers Are Cool*** Read about how water towers help provide a reliable water supply. • ***Energy Forms*** Read about different forms of energy and examples from everyday life.
Concepts	• Energy is the ability to do work. • Potential energy is stored energy. • Kinetic energy is energy of motion. • Gravitational potential energy works against gravity. • Energy can be transformed within a system.	• Changing an object's vertical position changes gravitational potential energy. • When work is done on an object, energy is transferred from one form into another. • Energy can be transformed within a system.	• Changing an object's mass changes gravitational potential energy. • When work is done on an object, energy is transferred from one form into another. • Energy can be transformed within a system. • As an object changes speed, its kinetic energy changes.	• Energy can be transformed within a system.	• Energy makes everyday life possible.
Key Terms	Gravitational potential energy Kinetic energy Model Potential energy Work	Dependent variable Gravitational potential energy Independent variable Kinetic energy System	Dependent variable Independent variable Kinetic energy Potential energy System	Diagram Graphical representation Gravitational potential energy Model	Chemical energy Elastic energy Electrical energy Electromagnetic energy Magnetic energy Mechanical energy Nuclear energy Solar energy Thermal energy
Assessment	Formative	Formative	Formative	Formative	Formative
Time	1 period	1 period	1 period	1 period	

Standards
ALIGNMENT TO NEXT GENERATION SCIENCE STANDARDS
Performance Expectations • MS-PS3-1 • MS-PS3-2 • MS-PS3-5
Science and Engineering Practices • Planning and carrying out investigations
• Obtaining, evaluating, and communicating information
Crosscutting Concepts • Cause and effect • Stability and change • Energy and matter • Connections to engineering,
Disciplinary Core Ideas • PS3.A: Definitions of energy • PS3.B: Conservation of energy and energy transfer • PS3.C: Relationship
CONNECTIONS
English Language Arts • RST.6-8.2 Key idea and details • RST.6-8.3 Key idea and details • RST.6-8.4 Craft and structure • RST.6-8.9 Integration of knowledge and ideas • RST.6-8.10 Range of reading and level of text complexity • SL.8.1 Comprehension and collaboration
Mathematics • 6.EE.A.2 Apply and extend previous understandings of arithmetic to algebraic expressions. • 6.EE.C.9 Represent and analyze quantitative relationships between dependent and independent variables.

…d Potential Energy **63b**

CONNECTIONS

English Language Arts
- RST.6-8.2 Key idea and details
- RST.6-8.3 Key idea and details
- RST.6-8.4 Craft and structure
- RST.6-8.9 Integration of knowledge and ideas
- RST.6-8.10 Range of reading and level of text complexity
- SL.8.1 Comprehension and collaboration
- WHST.6-8.1 Text types and purposes
- WHST.6-8.2 Text types and purposes
- WHST.6-8.7 Research to build and present knowledge
- WHST.6-8.9 Research to build and present knowledge

Mathematics
- 6.EE.A.2 Apply and extend previous understandings of arithmetic to algebraic expressions.
- 6.EE.C.9 Represent and analyze quantitative relation… between dependent and independent variables.

Daily ELA and Math support

ALIGNMENT TO NEXT GENERATION SCIENCE STANDARDS

Performance Expectations
- MS-PS3-1
- MS-PS3-2
- MS-PS3-5

Science and Engineering Practices
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Engaging in an argument from evidence
- Obtaining, evaluating, and communicating information

Crosscutting Concepts
- Cause and effect
- Stability and change
- Energy and matter
- Connections to engineering, technology, and applications of science: influence of science, engineering, and technology on society and the natural world

Disciplinary Core Ideas
- PS3.A: Definitions of energy
- PS3.B: Conservation of energy and energy transfer
- PS3.C: Relationship between energy and forces

Daily NGSS support

STCMS Concept Storylines' Coherent Learning Progression—Lesson by Lesson

For over 30 years, the Smithsonian Science Education Center has built inquiry science programs that work. What's the secret to their success? Concept Storylines that help construct learning using authentic STEM experiences.

Concept Storyline

Unit Driving Question: How can I affect the motion of objects?

Lesson 1: *Pre-Assessment: Let's Get Moving*

Focus Question: What do you know about energy, forces, and motion?

Students perform short, simple investigations that evaluate their existing knowledge of one or more concepts related to energy, forces, and motion. Students observe collisions, construct and analyze graphs, predict changes in motion, and model energy changes. Students also plan and carry out their own procedures and use engineering design skills to construct a balloon rocket.

Lesson 2: *Force, Velocity, and Acceleration*

Focus Question: Why do objects speed up, slow down, or change direction?

Students observe the motion of a rolling ball and investigate how mass and different surfaces affect its speed. Students consider how forces are involved in the ball's motion and predict how rolling a ball up or down an inclined plane will affect its speed. Students also investigate how mass relates to weight and prepare a graph showing the relationship.

Lesson 3: *Magnetic Forces*

Focus Question: How can magnets affect motion?

Students organize prior knowledge about magnets and magnetism and then distinguish between magnetic and nonmagnetic materials. Students plan and conduct investigations to determine how the force of a magnetic field is affected by magnet strength and distance from the magnet.

Lesson 4: *Newton's First and Second Laws*

Focus Question: How can we predict if the motion of an object will change or stay the same?

Students are introduced to Newton's first and second laws and apply their understanding to the motion of a dynamics car. Students plan investigations, predict the motion of a car, and construct explanations using evidence gathered during their investigations.

Lesson 5: *Kinetic and Gravitational Potential Energy*

Focus Question: How can gravity affect the motion of objects on Earth?

Students are introduced to gravitational potential energy and use a ball falling into sand to investigate how the mass or height of an object relates to potential and kinetic energy. Students develop a model to describe the energy of a system and use experimental evidence to support the claim that an energy transfer is responsible for changes in kinetic energy.

Lesson 6: *Newton's Third Law*

Focus Question: How would a ball move if you threw it in space?

Students are introduced to Newton's third law and use a battery-powered fan to determine the effects of balanced and unbalanced forces on the motion of a (dynamics) car. Students draw diagrams showing action-reaction force pairs and then apply Newton's third law to move a tennis ball in an engineering design challenge.

Lesson 7: *Collisions*

Focus Question: What happens to energy when two objects collide?

Students predict the motion of a dynamics car following a collision with a car of the same mass and a car of a different mass. Students apply the law of conservation of energy to explain energy transfer during a collision, develop a model to describe the total energy of the system, and apply Newton's three laws to explain the outcome of a collision.

Lesson 8: *Transforming Energy*

Focus Question: How do energy transformations inform the design of a roller coaster?

Students use foam pipe insulation to build a basic roller coaster that transforms gravitational potential energy into kinetic energy and can be used to test roller coaster design elements. Next, students construct a roller coaster that accomplishes a design challenge by defining criteria and constraints, evaluating competing design solutions, and testing and refining designs to optimize roller coaster performance.

Lesson 9: *Assessment: Energy, Forces and Motion*

Focus Question: How do people use an understanding of energy, forces, and motion to make predictions and design tools that make the world safe, enjoyable, and accessible?

The unit concludes with a two-part assessment. The first part is a Performance Assessment, in which students demonstrate their content knowledge and science and engineering skills to design a solution for transporting plastic fruit in a dynamics car without it falling off the vehicle. In the second part, students complete a Written Assessment covering the performance expectations, disciplinary core ideas, crosscutting concepts, and science and engineering practices covered in this unit.

Tab 1 / Unit Overview and Lesson Planner **9**

Within STCMS, each lesson:

- builds on the previous.
- provides rigorous investigation.
- begins with a Focus Question to drive daily instruction.

The STCMS Learning Framework—Conceptual Progression Unit by Unit

Every lesson builds on the previous. Each unit builds to the next. STCMS Concept Storylines show the pathway.

Three units in each strand of Physical, Life, and Earth/Space Science allows you to build your middle school program

by integrated approach →

or

by strand ↓

Physical Science	Life Science	Earth/Space Science
Energy, Forces, and Motion	Ecosystems and Their Interactions	Weather and Climate Systems
Matter and Its Interactions	Structure and Function	Earth's Dynamic Systems
Electricity, Waves, and Information Transfer	Genes and Molecular Machines	Space Systems Exploration

An example of how concepts can grow across a strand within STCMS

Physical Science Concepts

Energy, Forces, and Motion develops the energy background on how visible objects move and collide resulting in energy transfer and ending with how energy can be transformed.

↓

Matter and Its Interactions builds understanding of the relationship between energy and matter and transfer and transformation at the molecular level.

↓

Electricity, Waves, and Information Transfer studies and builds an understanding of the transfer and transformation of energy, how specific energies are transmitted by waves, and the technology contributions to society that have resulted from this understanding.

A step-by-step approach that builds a solid understanding in every strand of science.

Is It Really an NGSS Program?

7-Point NGSS Program Checklist—A Quick-Start Guide	
Five Innovations of NGSS	**Questions**
Three-Dimensional Construction	• Does the curriculum explicitly reflect and integrate all three dimensions of the NGSS and build to the Performance Expectations? • Are there multiple opportunities for students to master each dimension?
Focus on Engaging Phenomena	• Are students observing, investigating, modeling, and explaining phenomena? • Are they conducting inquiry science investigations and designing solutions? • Are they engaging?
Engineering Design and the Nature of Science	• Are engineering standards and science standards taught with equal importance? • Do learning experiences include Disciplinary Core Ideas of engineering design as well as the Science and Engineering Practices and Crosscutting Concepts of both engineering and the nature of science? • Are engineering design and the nature of science integrated throughout the science content and not separate lessons at the unit's end?
Coherent Learning Progression	• Is it clear that there is a coherent learning progression within each unit as well as across grade levels? • Is there a convincing concept storyline or other coherent framework? • Do units build on and extend knowledge and understanding gained in prior grades?
Connections to Math and ELA	• Are connections to the Mathematics and ELA Standards explicit?
Key Support Materials	
Materials	• Do students have the materials to carry out scientific investigations and engineering design projects?
Assessment	• Are there multiple assessments capable of evaluating student progress and the performance expectations, including the science and engineering practices?

So many programs claim to meet the NGSS, but how can you be sure? Use this 7-point NGSS program checklist as a guide.

	STCMS™	Where Is It in STCMS?
	✓ Yes	• Unit Overview lesson summaries show how Performance Expectations build over time • Alignment to Next Generation Science Standards before each lesson explicitly describes the integration of the Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices • Lessons that integrate real-world situations with scientific principles, leading to engaging and relevant instruction

	✓ Yes	• Focus Questions for each lesson that look at phenomena from a science perspective
		• Introductions that provide students with examples of phenomena that they can relate to
		• Investigations that:
		  • give students multiple opportunities to study, model, and explain phenomena
		  • provoke questions and call for the design of solutions

	✓ Yes	• Lesson at a Glance Alignment to Next Generation Science Standards • Lessons build an understanding of science and the world while incorporating meaningful engineering design opportunities • Lessons build an understanding of science content and develop use of evidence to revise design solutions
	✓ Yes	• Unit Concept Storylines show at a glance the conceptual progression over the course of the unit • Unit Table of Contents shows the focus on investigations and phenomena and on nonfiction support • STCMS Learning Framework illustrates the progression of concepts across grade levels and strands • Lessons that provide multiple opportunities for students to engage prior knowledge and experience investigative phenomena to deepen understanding and provide explanations
	✓ Yes	• Lesson at a Glance correlates ELA and Mathematics Standards for each lesson • Reading Selections that include discussion questions intentionally constructed to support ELA Standards • Teacher Edition includes explicit guidance on the importance of and the "how to" of connecting science and the Mathematics and ELA standards (Tab 3)
	✓ Yes	• Unit purchase includes the Teacher Edition, Student Editions—both with digital access—and all the materials to complete the investigations that are not commonly found in middle school science labs/classrooms.

	✓ Yes	• A coherent system of classroom-based assessments that provide powerful information to inform teaching and learning, for not only the teacher, but the student as well. STCMS units include:
		  • pre-assessment lesson
		  • formative assessment including Exit Slips to monitor student progress
		  • self-assessment for students
		  • summative assessment—performance and written components
		  • unit-specific NGSS rubrics to assess three-dimensional learning

Smithsonian | STC Science and Technology Concepts™ Middle School

Learning Framework

Units for Grades 6—8

Physical Science	Life Science	Earth/Space Science
Energy, Forces, and Motion PS2-1, PS2-2, PS2-3, PS2-5, PS3-1, PS3-2, PS3-5, ETS1-1, ETS1-2, ETS1-3, ETS1-4	**Ecosystems and Their Interactions** LS1-5, LS1-6, LS2-1, LS2-2, LS2-3, LS2-4, LS2-5, LS4-4, LS4-6, ESS3-3, ETS1-1, ETS1-2	**Weather and Climate Systems** ESS2-4, ESS2-5, ESS2-6, ESS3-2, ESS3-4, ESS3-5, PS3-4, ETS1-1, ETS1-2
Matter and Its Interactions PS1-1, PS1-2, PS1-3, PS1-4, PS1-5, PS1-6, PS3-4, ETS1-1, ETS1-2, ETS1-3, ETS1-4	**Structure and Function** LS1-1, LS1-2, LS1-3, LS1-6, LS1-7, LS1-8, LS4-2, LS4-3	**Earth's Dynamic Systems** LS4-1, ESS1-4, ESS2-1, ESS2-2, ESS2-3, ESS3-1,ESS3-2, ETS1-1, ETS1-2, ETS1-3, ETS1-4
Electricity, Waves, and Information Transfer LS1-8, PS2-3, PS2-5, PS3-3, PS3-4, PS3-5, PS4-1, PS4-2, PS4-3, ETS1-1, ETS1-2, ETS1-3, ETS1-4	**Genes and Molecular Machines** LS1-1, LS1-4, LS3-1, LS3-2,LS4-4, LS4-5	**Space Systems Exploration** PS2-4, ESS1-1, ESS1-2, ESS1-3, ETS1-1, ETS1-2

Three-dimensional learning for middle school

CCPST18031901