Shell Education

GRADE
6

180 Days of PRACTICE

HANDS-ON STEAM

Science | Technology | Engineering | Arts | Mathematics

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Science | Technology | Engineering | Arts | Mathematics

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NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

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Research

The Importance of STEAM Education

STEAM education is a powerful approach to learning that continues to gain momentum and support across the globe. STEAM is the integration of science, technology, engineering, the arts, and mathematics to design solutions for real-world problems. Students must learn how to question, explore, and analyze natural phenomena. With these skills in hand, students understand the complexity of available information and are empowered to become independent learners and problem solvers.

The content and practices of STEAM education are strong components of a balanced instructional approach, ensuring students are college- and career-ready. The application of STEAM practices in the classroom affords teachers opportunities to challenge students to apply new knowledge. Students of all ages can design and build structures, improve existing products, and test innovative solutions to real-world problems. STEAM instruction can be as simple as using recycled materials to design a habitat for caterpillars discovered on the playground and as challenging as designing a solution to provide clean water to developing countries. The possibilities are endless.

Blending arts principles with STEM disciplines prepares students to be problem solvers, creative collaborators, and thoughtful risk-takers. Even students who do not choose a career in a STEAM field will benefit because these skills can be translated into almost any career. Students who become STEAM proficient are prepared to answer complex questions, investigate global issues, and develop solutions for real-world challenges. Rodger W. Bybee (2013, 64) summarizes what is expected of students as they join the workforce:

> As literate adults, individuals should be competent to understand STEM-related global issues; recognize scientific from other nonscientific explanations; make reasonable arguments based on evidence; and, very important, fulfill their civic duties at the local, national, and global levels.

Likewise, STEAM helps students understand how concepts are connected as they gain proficiency in the Four Cs: creativity, collaboration, critical thinking, and communication.

Research *(cont.)*

Defining STEAM

STEAM is an integrated way of preparing students for the twenty-first century world. It places an emphasis on understanding science and mathematics while learning engineering skills. By including art, STEAM recognizes that the creative aspect of any project is integral to good design—whether designing an experiment or an object.

Science

Any project or advancement builds on prior science knowledge. Science focuses on learning and applying specific content, cross-cutting concepts, and scientific practices that are relevant to the topic or project.

Technology

This is what results from the application of scientific knowledge and engineering. It is something that is created to solve a problem or meet a need. Some people also include the *use* of technology in this category. That is, tools used by scientists and engineers to solve problems. In addition to computers and robots, technology can include nets used by marine biologists, anemometers used by meteorologists, computer software used by mathematicians, and so on.

Engineering

This is the application of scientific knowledge to meet a need, solve a problem, or address phenomena. For example, engineers design bridges to withstand huge loads. Engineering is also used to understand phenomena, such as in designing a way to test a hypothesis. When problems arise, such as those due to earthquakes or rising sea levels, engineering is required to design solutions to the problems. On a smaller scale, a homeowner might want to find a solution to their basement flooding.

Art

In this context, art equals creativity and creative problem-solving. For example, someone might want to test a hypothesis but be stumped as to how to set up the experiment. Perhaps you have a valuable painting. You think there is another valuable image below the first layer of paint on the canvas. You do not want to destroy the painting on top. A creative solution is needed. Art can also include a creative or beautiful design that solves a problem. For example, the Golden Gate Bridge is considered both an engineering marvel and a work of art.

Mathematics

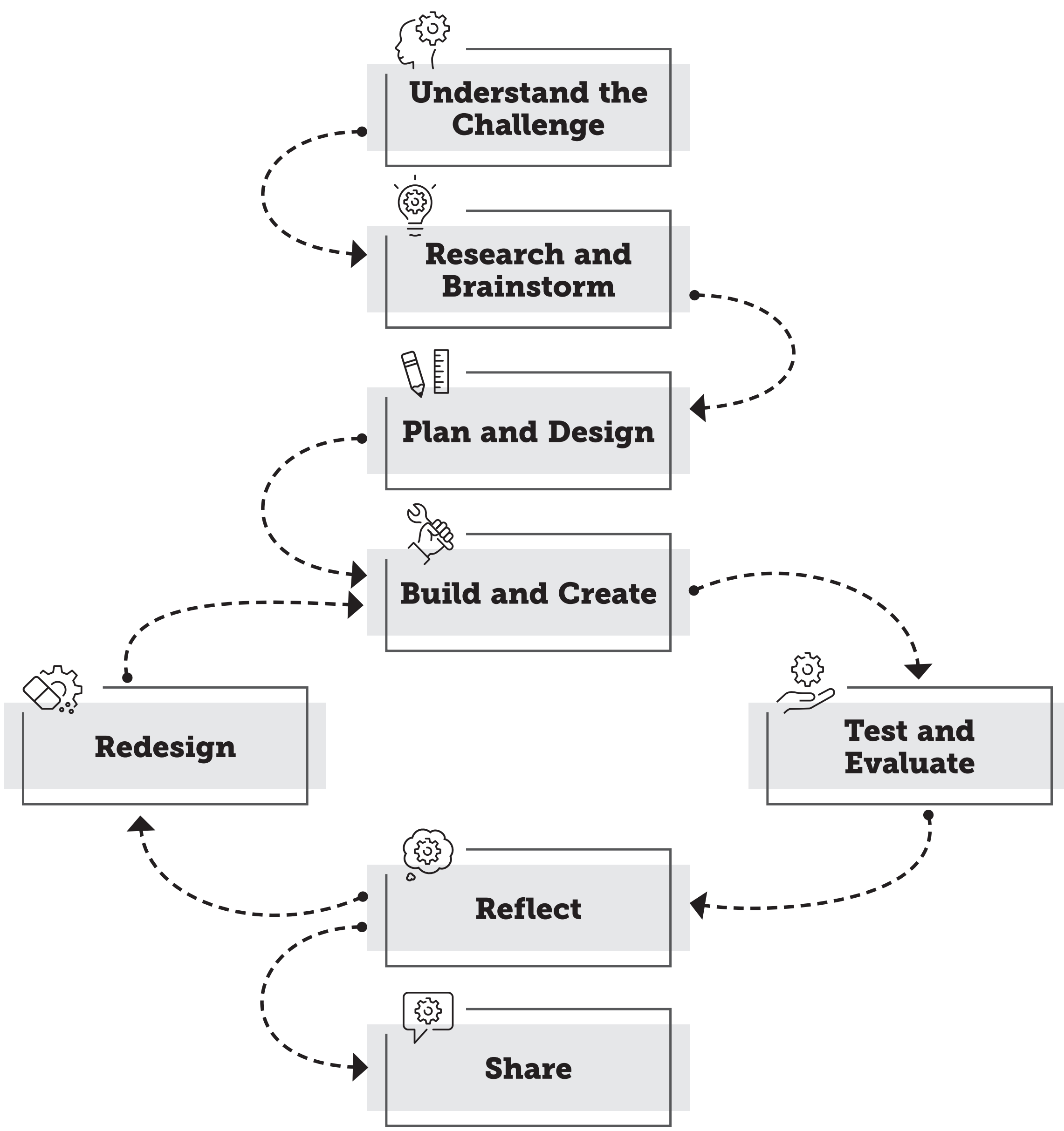
This is the application of mathematics to real-world problems. Often, this includes data analysis—such as collecting data, graphing it, analyzing the data, and then communicating that analysis. It may also include taking mathematical measurements in the pursuit of an answer. The idea is not to learn new math, but rather to apply it; however, some mathematics may need to be learned to solve the specific problem. Isaac Newton, for example, is famous for *inventing* calculus to help him solve problems in understanding gravity and motion.

Research *(cont.)*

The Engineering Design Process

The most essential component of STEAM education is the engineering design process. This process is an articulated approach to problem solving in which students are guided through the iterative process of solving problems and refining solutions to achieve the best possible outcomes. There are many different versions of the engineering design process, but they all have the same basic structure and goals. As explained in Appendix I of NGSS (2013), "At any stage, a problem-solver can redefine the problem or generate new solutions to replace an idea that just isn't working out."

Each unit in this resource presents students with a design challenge in an authentic and engaging context. The practice pages guide and support students through the engineering design process to solve problems or fulfill needs.



Research *(cont.)*

How to Facilitate Successful STEAM Challenges

There are some basic rules to remember as your students complete STEAM challenges.

Both independent and collaborative work should be included.

Astronaut and inventor Ellen Ochoa is well-known for working a robotic arm in space. About that experience she said, "It's fun to work the robotic arm, in part because it's a team effort." She recognized that she was getting credit for something amazing that happened because of the collaborative work of hundreds of people.

Students need time to think through a project, both on their own and together with others. It is often best to encourage students to start by thinking independently. One student may think of a totally different solution than another student. Once they come together, students can merge aspects of each other's ideas to devise something even better.

Failure is a step in the process.

During the process of trying to invent a useful light bulb, Thomas Edison famously said, "I have not failed. I've just found 10,000 ways that won't work." People are innovating when they are failing because it is a chance to try something new. The STEAM challenges in this book intentionally give students chances to improve their designs. Students should feel free to innovate as much as possible, especially the first time around. Then, they can build on what they learned and try again.

Some students get stuck thinking there is one right way. There are almost always multiple solutions to a problem. For example, attaching train cars together used to be very dangerous. In the late nineteenth century, different solutions to this problem were invented in England and the United States to make the process safer. Both solutions worked, and both were used! Encourage students to recognize that there are usually different ways to solve problems. Discuss the pros and cons of the various solutions that students generate.

Research *(cont.)*

How to Facilitate Successful STEAM Challenges *(cont.)*

Getting inspiration from others is an option.

Students worry a lot about copying. It is important to remind them that all breakthroughs come on the shoulders of others. No one is working in a vacuum, and it is okay to get inspiration and ideas from others. It is also important to give credit to the people whose work and ideas inspired others. Students may see this as cheating, but they should be encouraged to see that they had a great enough idea that others recognized it and wanted to build on it.

The struggle is real—and really important.

Most people do not like to fail. And it can be frustrating not to know what to do or what to try next. Lonnie Johnson, engineer and toy inventor, advises, "Persevere. That's what I always say to people. There's no easy route." Try to support students during this struggle, as amazing innovations can emerge from the process. Further, students feel great when they surprise themselves with success after thinking they were not going to succeed.

Materials can inspire the process.

Students may be stumped about how they are going to build a boat…until you show them that they can use clay. A parachute is daunting, but a pile of tissue paper or plastic bags might suddenly make students feel like they have some direction. On the other hand, materials can also instantly send the mind in certain directions, without exploring other options. For this reason, consider carefully the point at which you want to show students the materials they can use. You might want them to brainstorm materials first. This might inspire you to offer materials you had not considered before.

Some students or groups will need different types of support.

If possible, have students who need additional support manipulate materials, play with commercial solutions, or watch videos to get ideas. For students who need an additional challenge, consider ways to make the challenge more "real world" by adding additional realistic criteria. Or, encourage students to add their own criteria.

How to Use This Resource

Unit Structure Overview

This resource is organized into 12 units. Each three-week unit is organized in a consistent format for ease of use.

Week 1: STEAM Content

Day 1 **Learn Content**	Students read text, study visuals, and answer multiple-choice questions.
Day 2 **Learn Content**	Students read text, study visuals, and answer short-answer questions.
Day 3 **Explore Content**	Students engage in hands-on activities, such as scientific investigations, mini building challenges, and drawing and labeling diagrams.
Day 4 **Get Creative**	Students use their creativity, imaginations, and artistic abilities in activities such as drawing, creating fun designs, and doing science-related crafts.
Day 5 **Analyze Data**	Students analyze and/or create charts, tables, maps, and graphs.

Week 2: STEAM Challenge

Day 1 **Understand the Challenge**	Students are introduced to the STEAM Challenge. They review the criteria and constraints for successful designs.
Day 2 **Research and Brainstorm**	Students conduct additional research, as needed, and brainstorm ideas for their designs.
Day 3 **Plan and Design**	Students plan and sketch their designs.
Day 4 **Build and Create**	Students use their materials to construct their designs.
Day 5 **Test and Evaluate**	Students conduct tests and/or evaluation to assess the effectiveness of their designs and how well they met the criteria of the challenge.

Week 3: STEAM Challenge Improvement

Day 1 **Reflect**	Students answer questions to reflect on their first designs and make plans for how to improve their designs.
Day 2 **Redesign**	Students sketch new or modified designs.
Day 3 **Rebuild and Refine**	Students rebuild or adjust their designs.
Day 4 **Retest**	Students retest and evaluate their new designs.
Day 5 **Reflect and Share**	Students reflect on their experiences working through the engineering design process. They discuss and share their process and results with others.

How to Use This Resource *(cont.)*

Pacing Options

This resource is flexibly designed and can be used in tandem with a core curriculum within a science, STEAM, or STEM block. It can also be used in makerspaces, after-school programs, summer school, or as enrichment activities at home. The following pacing options show suggestions for how to use this book.

Option 1

This option shows how each unit can be completed in 15 days. This option requires approximately 10–20 minutes per day. Building days are flexible, and teachers may allow for additional time at their discretion.

	Day 1	Day 2	Day 3	Day 4	Day 5
Week 1	Learn Content	Learn Content	Explore Content	Get Creative	Analyze Data
Week 2	Understand the Challenge	Research and Brainstorm	Plan and Design	Build and Create	Test and Evaluate
Week 3	Reflect	Redesign	Rebuild and Refine	Retest	Reflect and Share

Option 2

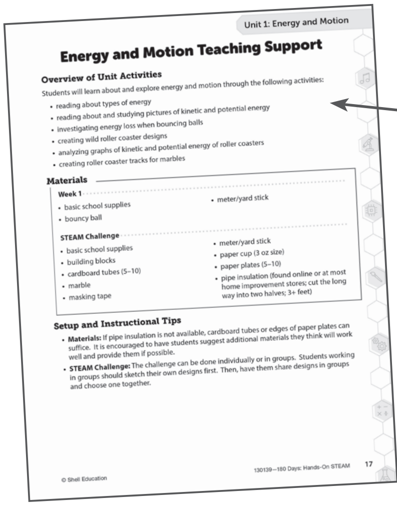
This option shows how each unit can be completed in fewer than 15 days. This option requires approximately 45–60 minutes a day.

	Day 1	Day 2
Week 1	Learn Content Explore Content	Get Creative Analyze Data
Week 2	Understand the Challenge Research and Brainstorm Plan and Design	Build and Create Test and Evaluate
Week 3	Reflect Redesign Rebuild and Refine	Retest Reflect and Share

How to Use This Resource *(cont.)*

Teaching Support Pages

Each unit in this resource begins with two teaching support pages that provide instructional guidance.


Unit 1: Energy and Motion

Energy and Motion Teaching Support

Overview of Unit Activities

Students will learn about and explore energy and motion through the following activities:

- reading about types of energy
- reading about and studying pictures of kinetic and potential energy
- investigating energy loss when bouncing balls
- creating wild roller coaster designs
- analyzing graphs of kinetic and potential energy of roller coasters
- creating roller coaster tracks for marbles

Materials

Week 1
- basic school supplies
- bouncy ball
- meter/yard stick

STEAM Challenge
- basic school supplies
- building blocks
- cardboard tubes (5–10)
- marble
- masking tape
- meter/yard stick
- paper cup (3 oz size)
- paper plates (5–10)
- pipe insulation (found online or at most home improvement stores; cut the long way into two halves; 3+ feet)

Setup and Instructional Tips
- **Materials:** If pipe insulation is not available, cardboard tubes or edges of paper plates can suffice. It is encouraged to have students suggest additional materials they think will work well and provide them if possible.
- **STEAM Challenge:** The challenge can be done individually or in groups. Students working in groups should sketch their own designs first. Then, have them share designs in groups and choose one together.

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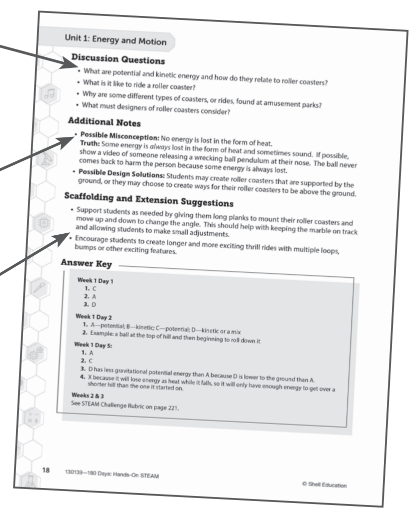
A clear overview of unit activities, weekly materials, safety notes, and setup tips helps teachers plan and prepare efficiently and with ease.

Discussion questions encourage students to verbalize their learning and connect it to their own lives.

Possible student misconceptions and design solutions further take the guesswork out of lesson planning.

Differentiation options offer ways to support and extend student learning.


Unit 1: Energy and Motion

Discussion Questions
- What are potential and kinetic energy and how do they relate to roller coasters?
- What is it like to ride a roller coaster?
- Why are some different types of coasters, or rides, found at amusement parks?
- What must designers of roller coasters consider?

Additional Notes
- **Possible Misconception:** No energy is lost in the form of heat.
  Truth: Some energy is *always* lost in the form of heat and sometimes sound. If possible, show a video of someone releasing a wrecking ball pendulum at their nose. The ball never comes back to harm the person because some energy is always lost.
- **Possible Design Solutions:** Students may create roller coasters that are supported by the ground, or they may choose to create ways for their roller coasters to be above the ground.

Scaffolding and Extension Suggestions
- Support students as needed by giving them long planks to mount their roller coasters and move up and down to change the angle. This should help with keeping the marble on track and allowing students to make small adjustments.
- Encourage students to create longer and more exciting thrill rides with multiple loops, bumps or other exciting features.

Answer Key

Week 1 Day 1
1. C
2. A
3. D

Week 1 Day 2
1. A—potential; B—kinetic; C—potential; D—kinetic or a mix
2. Example: a ball at the top of hill and then beginning to roll down it

Week 1 Day 5:
1. A
2. C
3. D has less gravitational potential energy than A because D is lower to the ground than A.
4. X because it will lose energy as heat while it falls, so it will only have enough energy to get over a shorter hill than the one it started on.

Weeks 2 & 3

See STEAM Challenge Rubric on page 221.

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Materials

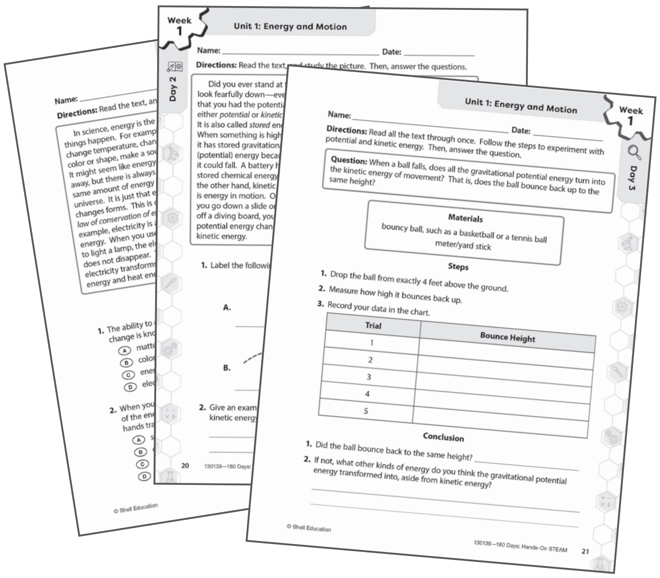
Due to the nature of engineering, the materials listed are often flexible. They may be substituted or added to, depending on what you have available. More material options require greater consideration by students and encourage more creative and critical thinking. Fewer material options can help narrow students' focus but may limit creativity. Adjust the materials provided to fit the needs of your students.

Approximate amounts of materials are included in each list. These amount suggestions are per group. Students are expected to have basic school supplies for each unit. These include paper, pencils, markers or crayons, glue, tape, and scissors.

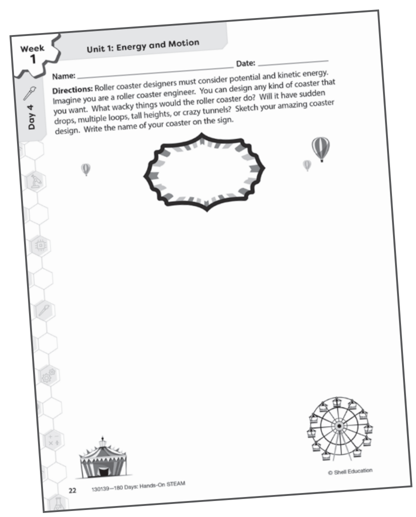
How to Use This Resource *(cont.)*

Student Pages

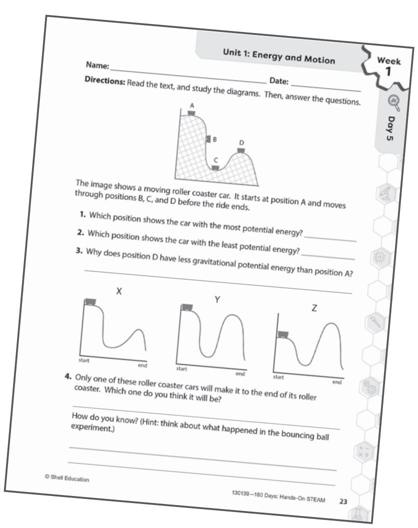
Students begin each unit by learning about and exploring science-related content.



Activities in **Week 1** help build background science content knowledge relevant to the STEAM Challenge.



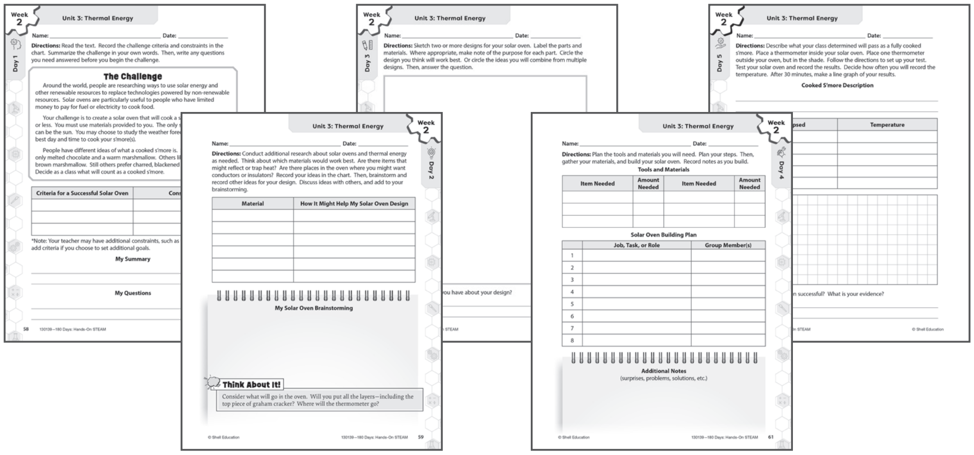
Creative activities encourage students to connect science and art.



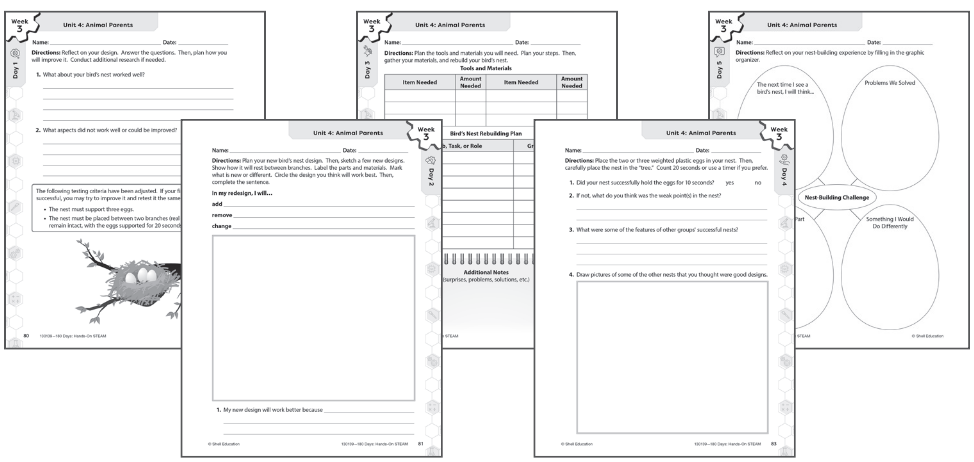
Graphs, charts, and maps guide students to make important mathematics and real-world connections.

How to Use This Resource *(cont.)*

Student Pages *(cont.)*



Week 2 introduces students to the STEAM Challenge. Activities guide students through each step of the engineering design process. They provide guiding questions and space for students to record their plans, progress, results, and thinking.



Week 3 activities continue to lead students through the cycle of the engineering design process. Students are encouraged to think about and discuss ways to improve their designs based on their observations and experiences in Week 2.

Quick Tip!

Staple all the student pages for each unit together, and distribute them as packets. This will allow students to easily refer to their learning as they complete the STEAM Challenges.

How to Use This Resource *(cont.)*

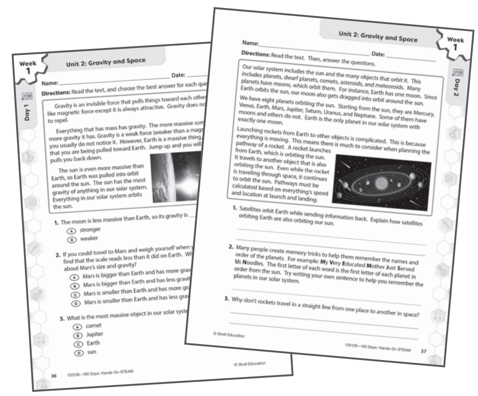
Assessment Options

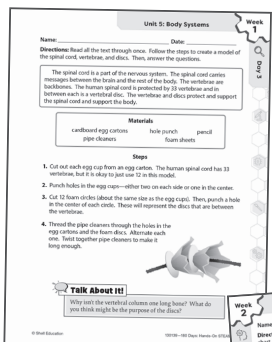
Assessments guide instructional decisions and improve student learning. This resource offers balanced assessment opportunities. The assessments require students to think critically, respond to text-dependent questions, and utilize science and engineering practices.

Progress Monitoring

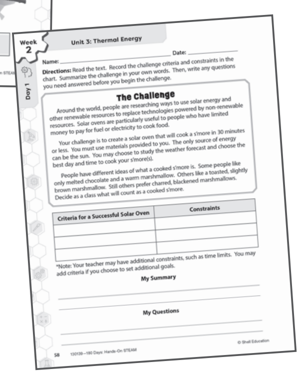
There are key points throughout each unit when valuable formative evaluations can be made. These evaluations can be based on group, paired, and/or individual discussions and activities.

- **Week 1** activities provide opportunities for students to answer multiple-choice and short-answer questions related to the content. Answer keys for these pages are provided in the Teaching Support pages.

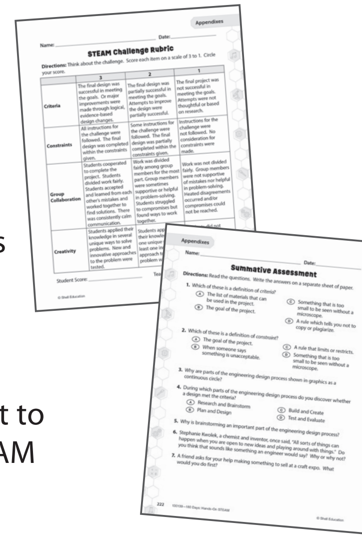




- **Talk About It!** graphics on student activity sheets offer opportunities to monitor student progress.



- **Week 2 Day 3: Plan and Design** is when students sketch their first designs. This is a great opportunity to assess how well students understand the STEAM challenge and what they plan to create. These should be reviewed before moving on to the Build and Create stages of the STEAM Challenges.



Summative Assessment

A rubric for the STEAM Challenges is provided on page 221. It is important to note that whether students' final designs were successful is not the main goal of this assessment. It is a way to assess students' skills as they work through the engineering design process. Students assess themselves first. Teachers can add notes to the assessment.

A short summative assessment is provided on page 222. This is meant to provide teachers with insight into how well students understand STEAM practices and the engineering design process.

Standards Correlations

Shell Education is committed to producing educational materials that are research and standards based. To support this effort, this resource is correlated to the academic standards of all 50 states, the District of Columbia, the Department of Defense Dependent Schools, and the Canadian provinces. A correlation is also provided for key professional educational organizations.

To print a customized correlation report for your state, visit our website at **www.tcmpub.com/administrators/correlations** and follow the online directions. If you require assistance in printing correlation reports, please contact the Customer Service Department at 1-800-858-7339.

Standards Overview

The Every Student Succeeds Act (ESSA) mandates that all states adopt challenging academic standards that help students meet the goal of college and career readiness. While many states already adopted academic standards prior to ESSA, the act continues to hold states accountable for detailed and comprehensive standards. Standards are designed to focus instruction and guide adoption of curricula. They define the knowledge, skills, and content students should acquire at each level. Standards are also used to develop standardized tests to evaluate students' academic progress. State standards are used in the development of our resources, so educators can be assured they meet state academic requirements.

Next Generation Science Standards

This set of national standards aims to incorporate science knowledge and process standards into a cohesive framework. The standards listed on page 16 describe the science content and processes presented throughout the lessons.

TESOL and WIDA Standards

In this book, the following English language development standards are met: Standard 1: English language learners communicate for social and instructional purposes within the school setting. Standard 3: English language learners communicate information, ideas and concepts necessary for academic success in the content area of mathematics. Standard 4: English language learners communicate information, ideas and concepts necessary for academic success in the content area of science.

Standards Correlations *(cont.)*

Each unit in this resource supports the following NGSS Scientific and Engineering Practices and Engineering Performance Expectations for 6–8.

Scientific and Engineering Practices	Engineering Performance Expectations
Asking Questions and Defining Problems	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
Developing and Using Models	
Planning and Carrying Out Investigations	
Analyzing and Interpreting Data	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
Constructing Explanations and Designing Solutions	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
Engaging in Argument from Evidence	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
Obtaining, Evaluating, and Communicating Information	

This chart shows how the units in this resource align to NGSS Disciplinary Core Ideas and Crosscutting Concepts.

Unit	Disciplinary Core Idea	Crosscutting Concept
Energy and Motion	PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Scale, Proportion, and Quantity; Energy and Matter
Gravity and Space	PS2.B: Types of Interactions ESS1.B: Earth and the Solar System	Scale, Proportion, and Quantity; Systems and System Models
Thermal Energy	PS3.A: Definitions of Energy	Energy and Matter
Animal Parents	LS1.B: Growth and Development of Organisms LS1.C: Organization for Matter and Energy Flow in Organisms	Structure and Function
Body Systems	LS1.A: Structure and Function	Systems and System Models
Cells	LS1.A: Structure and Function	Systems and System Models
Plant Reproduction	LS1.B: Growth and Development of Organisms	Structure and Function
Air and Weather	ESS2.D: Weather and Climate	Cause and Effect
Earth's Materials	ESS2.A: Earth Materials and Systems ESS1.C: The History of Planet Earth	Stability and Change
Ocean Currents	ESS2.D: Weather and Climate ESS2.C: The Roles of Water in Earth's Surface Processes ESS3.D: Global Climate Change	Systems and System Models
Plate Tectonics	ESS2.B: Plate Tectonics and Large-Scale System Interactions ESS3.B: Natural Hazards	Cause and Effect; Patterns; Scale, Proportion, and Quantity
The Water Cycle	ESS2.C: The Roles of Water in Earth's Surface Processes	Energy and Matter

Energy and Motion Teaching Support

Overview of Unit Activities

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Materials Per Group

Week 1

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- meter/yard stick

STEAM Challenge

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- marble
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- paper plates (5–10)
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- Why are some different types of coasters, or rides, found at amusement parks?
- What must designers of roller coasters consider?

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- **Possible Design Solutions:** Students may create roller coasters that are supported by the ground, or they may choose to create ways for their roller coasters to be above the ground.

Scaffolding and Extension Suggestions

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- Encourage students to create longer and more exciting thrill rides with multiple loops, bumps, or other exciting features.

Answer Key

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2. A
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Week 1 Day 2

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2. Example: a ball at the top of hill and then beginning to roll down it

Week 1 Day 5:

1. A
2. C
3. D has less gravitational potential energy than A because D is lower to the ground than A.
4. X because it will lose energy as heat while it falls, so it will only have enough energy to get over a shorter hill than the one it started on.

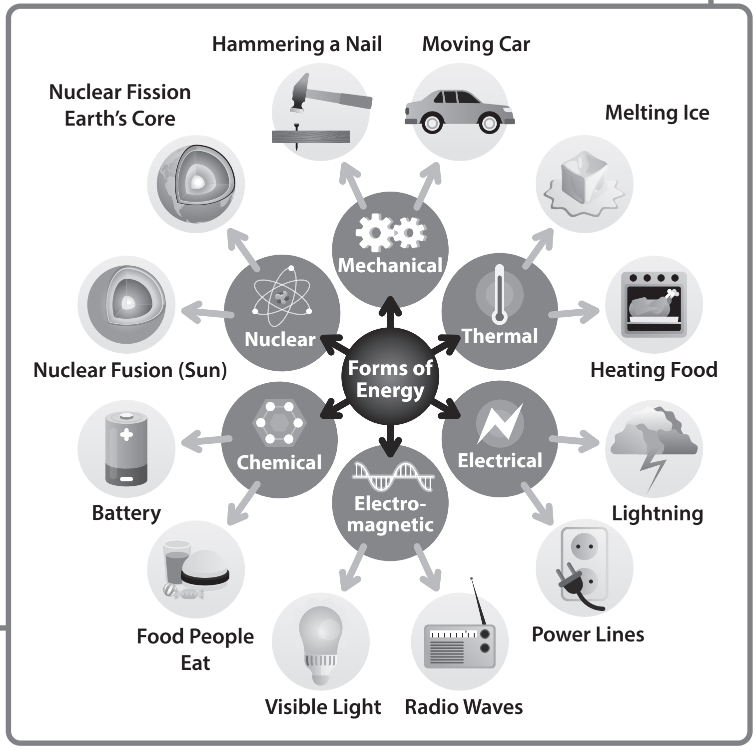
Weeks 2 & 3

See STEAM Challenge Rubric on page 221.

Name: ____________________ Date: ____________

Directions: Read the text, and choose the best answer for each question.

In science, energy is the ability to do work. This means energy can make things happen. For example, energy can: make things move (or stop moving), change temperature, change color or shape, make a sound. It might seem like energy goes away, but there is always the same amount of energy in the universe. It is just that energy changes forms. This is called the *law of conservation of energy*. For example, electricity is a form of energy. When you use electricity to light a lamp, the electricity does not disappear. The electricity transforms into light energy and heat energy.



1. The ability to do work or cause change is known as __________.
   - (A) matter
   - (B) color
   - (C) energy
   - (D) electricity

2. When you clap your hands, some of the energy of the motion of your hands transforms into __________.
   - (A) sound
   - (B) color
   - (C) electricity
   - (D) light

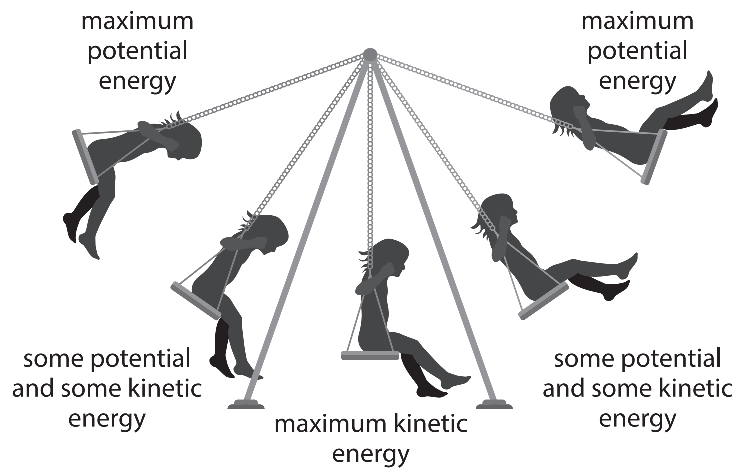
3. What does the law of conservation of energy state?
   - (A) Energy cannot be destroyed.
   - (B) Energy cannot be created.
   - (C) Energy can change from one form to another.
   - (D) All the above.

Name: ______________________________ Date: ______________

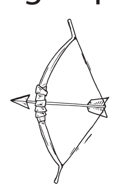
Directions: Read the text, and study the diagram. Then, answer the questions.

Did you ever stand at the top of a diving board or playground slide and look fearfully down—even when you were little? That is because you knew that you had the potential to come down fast! Energy is often described as either *potential* or *kinetic* energy. Potential energy is work that *could* happen. It is also called *stored* energy. When something is high up, it has stored gravitational (potential) energy because it could fall. A battery has stored chemical energy. On the other hand, kinetic energy is energy in motion. Once you go down a slide or jump off a diving board, your potential energy changes to kinetic energy.

Pendulum Motion



1. Label the following as potential or kinetic energy.

A. 

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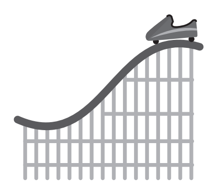
C. 

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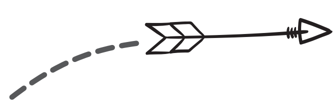
B. 

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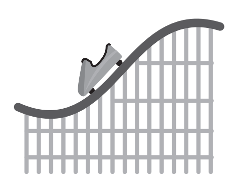
D. 

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2. Give an example of something that has potential energy that changes into kinetic energy.

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Name: ______________________________ Date: ______________

Directions: Read all the text through once. Follow the steps to experiment with potential and kinetic energy. Then, answer the question.

Question: When a ball falls, does all the gravitational potential energy turn into the kinetic energy of movement? That is, does the ball bounce back up to the same height?

Materials

bouncy ball, such as a basketball or a tennis ball

meter/yard stick

Steps

1. Drop the ball from exactly 4 feet (1.2 m) above the ground.
2. Measure how high it bounces back up.
3. Record your data in the chart.

Trial	Bounce Height
1	
2	
3	
4	
5	

Conclusion

1. Did the ball bounce back to the same height? ______________________
2. If not, what other kinds of energy do you think the gravitational potential energy transformed into, aside from kinetic energy?

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Name: ______________________________ **Date:** ________________

Directions: Roller coaster designers must consider potential and kinetic energy. Imagine you are a roller coaster engineer. You can design any kind of coaster that you want. What wacky things would the roller coaster do? Will it have sudden drops, multiple loops, tall heights, or crazy tunnels? Sketch your amazing coaster design. Write the name of your coaster on the sign.