HMH

HMH Science Dimensions®

GRADES 9–12

Earth & Space Science

ENGINEERED for the Next Generation

PROGRAM RESOURCES AND FEATURES

Explore.
Experiment.
Experience.

HMH Science Dimensions

A Comprehensive K–12 Solution Engineered for Success

Envision a classroom where students ask questions, state claims, test their ideas, and find resolution through reasoning. With increased demand for science proficiency in the workplace, it is imperative to cultivate the creative problem solvers who will go on to become the next generation of innovators.

With built-in support and a transformed lesson structure, instructors will become facilitators who empower their students to learn through self-directed exploration, analysis, application, and explanation—in short, to think like scientists.

Inspire the next generation of scientists and innovators

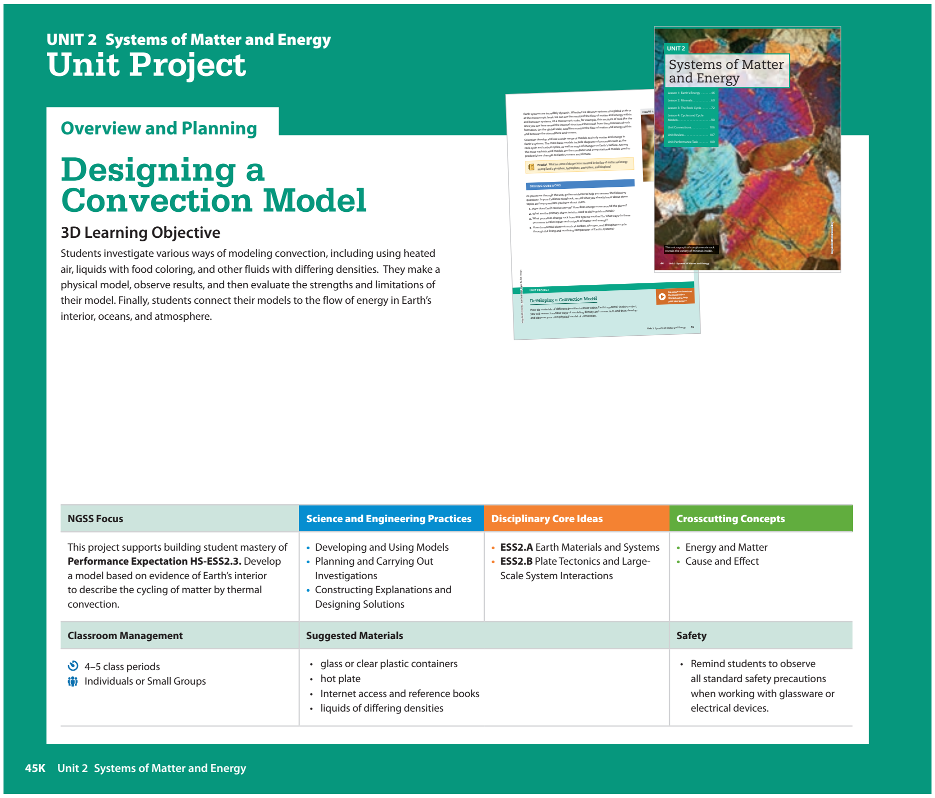
- Foster student engagement through **phenomena-based lessons**.
- Promote active learning with **investigation-driven activities**.
- Build excitement for **engineering and STEM**.
- Build and evaluate problem-solving skills with **Performance-Based Assessment**.
- Engage students with motivating **digital resources,** including You Solve It! simulations.
- Create enduring understanding with **integrated three-dimensional learning**.
- Develop effective Next Generation Science Standards* (NGSS) approaches with **embedded professional learning.**

Build Student Confidence with Authentic Investigations

Students are more engaged and learn more meaningfully through investigative inquiry. *HMH Science Dimensions® Earth & Space Science* is built on this approach. Your students will learn to define questions, design and conduct hands-on investigations, make **claims**, gather **evidence**, and use **reasoning** to explain phenomena. Watch as they take charge and fully engage in their learning!

Unit Projects with Anchoring Phenomena

Unit Projects are performance-based activities that stem from an anchoring phenomenon and incorporate the Three Dimensions of Learning addressed in the unit lessons.



UNIT 2 **Systems of Matter and Energy**

Unit Project

Overview and Planning

Designing a Convection Model

3D Learning Objective

Students investigate various ways of modeling convection, including using heated air, liquids with food coloring, and other fluids with differing densities. They make a physical model, observe results, and then evaluate the strengths and limitations of their model. Finally, students connect their models to the flow of energy in Earth's interior, oceans, and atmosphere.

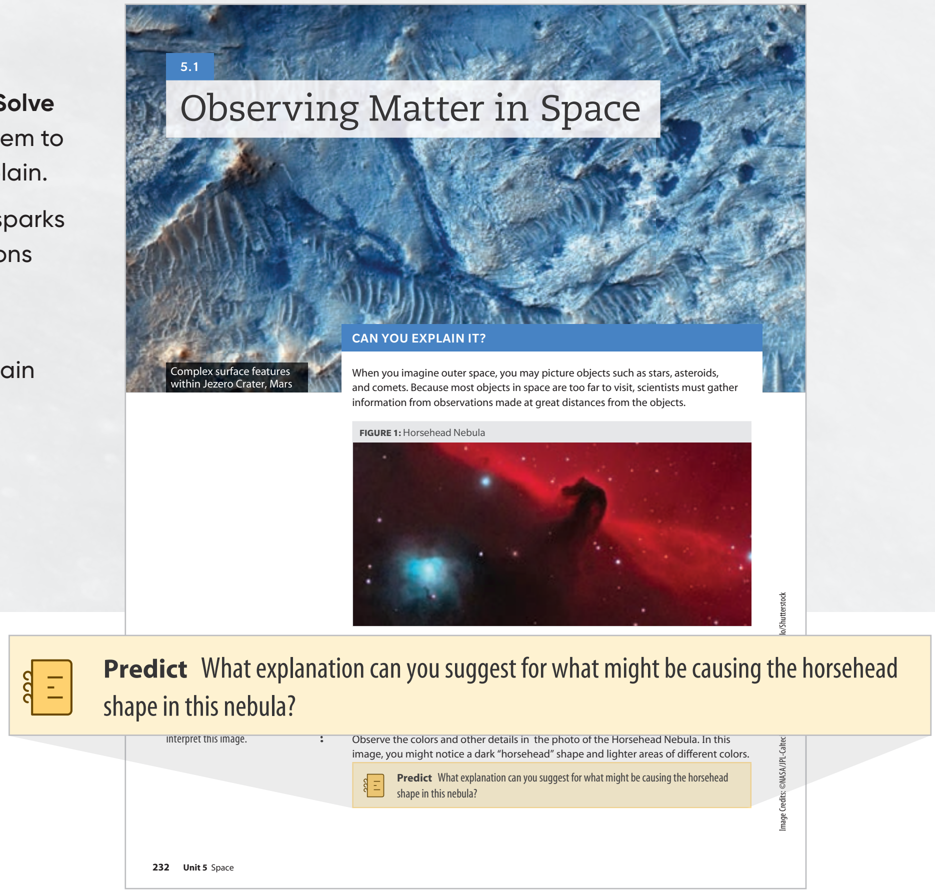
NGSS Focus	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
This project supports building student mastery of **Performance Expectation HS-ESS2.3.** Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	• Developing and Using Models • Planning and Carrying Out Investigations • Constructing Explanations and Designing Solutions	• **ESS2.A** Earth Materials and Systems • **ESS2.B** Plate Tectonics and Large-Scale System Interactions	• Energy and Matter • Cause and Effect
Classroom Management	**Suggested Materials**		**Safety**
4–5 class periods Individuals or Small Groups	• glass or clear plastic containers • hot plate • Internet access and reference books • liquids of differing densities		• Remind students to observe all standard safety precautions when working with glassware or electrical devices.

45K Unit 2 Systems of Matter and Energy

Investigative Phenomena Lead Every Lesson

Each lesson begins with **Can You Solve It?** or **Can You Explain It?**—a problem to solve or a discrepant event to explain.

- The investigative phenomenon sparks curiosity with compelling situations and real-world connections.
- Throughout the lesson, students gather evidence to solve or explain the phenomenon.
- Data analysis leads students to construct evidence-based explanations.



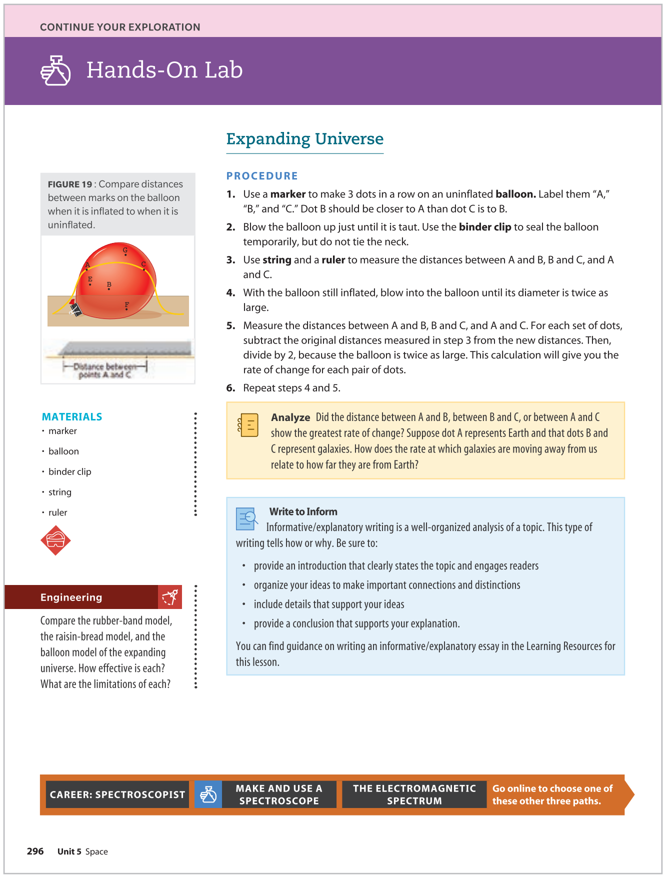
Science Notebooking to Strengthen Writing Skills

HMH Science Dimensions Earth & Space Science supports the use of **Evidence Notebooks**. Helpful prompts inserted throughout the lessons guide students on entries for their notebooks. Students will love creating study guides they can use, and teachers will love the extra reasoning through writing!

GATHER EVIDENCE

Make notes about patterns you've observed in this Exploration that could help you interpret images of nebulae, such as the Horsehead nebula shown in Lesson 1.

Includes anchor, investigative, and everyday phenomena in every unit


CONTINUE YOUR EXPLORATION

Hands-On Lab

Expanding Universe

FIGURE 19 : Compare distances between marks on the balloon when it is inflated to when it is uninflated.

Distance between points A and C

PROCEDURE

1. Use a **marker** to make 3 dots in a row on an uninflated **balloon.** Label them "A," "B," and "C." Dot B should be closer to A than dot C is to B.
2. Blow the balloon up just until it is taut. Use the **binder clip** to seal the balloon temporarily, but do not tie the neck.
3. Use **string** and a **ruler** to measure the distances between A and B, B and C, and A and C.
4. With the balloon still inflated, blow into the balloon until its diameter is twice as large.
5. Measure the distances between A and B, B and C, and A and C. For each set of dots, subtract the original distances measured in step 3 from the new distances. Then, divide by 2, because the balloon is twice as large. This calculation will give you the rate of change for each pair of dots.
6. Repeat steps 4 and 5.

MATERIALS
- marker
- balloon
- binder clip
- string
- ruler

Analyze Did the distance between A and B, between B and C, or between A and C show the greatest rate of change? Suppose dot A represents Earth and that dots B and C represent galaxies. How does the rate at which galaxies are moving away from us relate to how far they are from Earth?

Engineering

Compare the rubber-band model, the raisin-bread model, and the balloon model of the expanding universe. How effective is each? What are the limitations of each?

Write to Inform
Informative/explanatory writing is a well-organized analysis of a topic. This type of writing tells how or why. Be sure to:

- provide an introduction that clearly states the topic and engages readers
- organize your ideas to make important connections and distinctions
- include details that support your ideas
- provide a conclusion that supports your explanation.

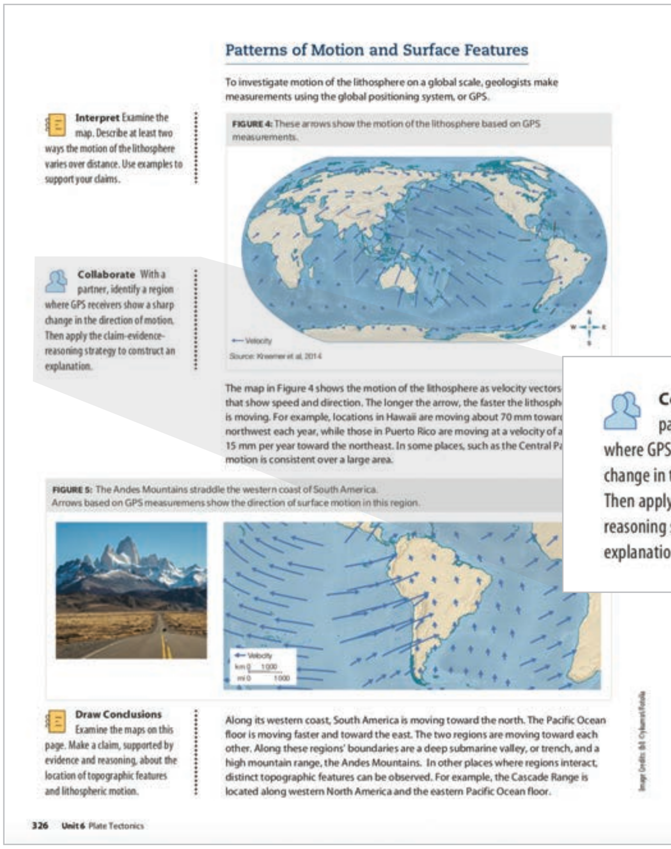
You can find guidance on writing an informative/explanatory essay in the Learning Resources for this lesson.

CAREER: SPECTROSCOPIST | MAKE AND USE A SPECTROSCOPE | THE ELECTROMAGNETIC SPECTRUM | Go online to choose one of these other three paths.

296 Unit 5 Space

Real-World Labs for Real-World Issues

- Labs integrated at point of use are designed to use easily sourced materials.
- Activities prompt students to gather evidence and work towards resolution of the phenomena.
- Students actively "do science"; they think critically about their observations, gather evidence, and defend their claims.



Collaborate With a partner, identify a region where GPS receivers show a sharp change in the direction of motion. Then apply the claim-evidence-reasoning strategy to construct an explanation.

Cultivate Collaboration

Scientists do not work in isolation and neither will your students as they:

- Collaborate to complete activities
- Partner with peers to discuss findings
- Participate in group and classroom-based discussions

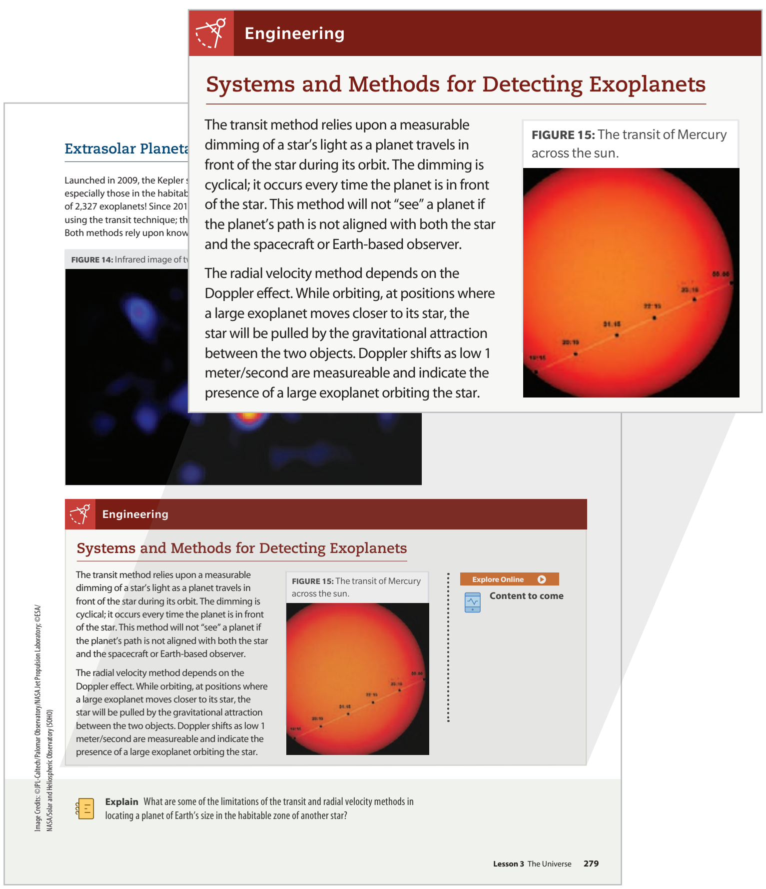
DIFFERENTIATE THROUGH HUMOROUS EXPLANATIONS

Through an exclusive partnership with author and internet sensation Randall Munroe, HMH® has incorporated material from Munroe's latest book, ***Thing Explainer***, into our print and digital editions.

By adding humor to the drawings and descriptions, Munroe's Thing Explainers provide a fun way to convey and clarify information.

Today's Students Will Solve the Technology and Engineering Challenges of Tomorrow!

HMH Science Dimensions Earth & Space Science moves students beyond only learning science content to a focus on what students can do with that knowledge by embedding engineering throughout every unit.



Engineering

Systems and Methods for Detecting Exoplanets

The transit method relies upon a measurable dimming of a star's light as a planet travels in front of the star during its orbit. The dimming is cyclical; it occurs every time the planet is in front of the star. This method will not "see" a planet if the planet's path is not aligned with both the star and the spacecraft or Earth-based observer.

The radial velocity method depends on the Doppler effect. While orbiting, at positions where a large exoplanet moves closer to its star, the star will be pulled by the gravitational attraction between the two objects. Doppler shifts as low 1 meter/second are measureable and indicate the presence of a large exoplanet orbiting the star.

FIGURE 15: The transit of Mercury across the sun.

Explain What are some of the limitations of the transit and radial velocity methods in locating a planet of Earth's size in the habitable zone of another star?

Lesson 3 The Universe 279

Integrated Engineering

In *HMH Science Dimensions Earth & Space Science*, students embrace the engineering process as they:

- Analyze global challenges and the resources available to meet society's needs
- Break down complex, real-world issues into manageable problems that can be solved through engineering
- Evaluate the criteria and constraints of engineering solutions as well as potential social, cultural, and environmental impacts
- Use computer simulations to model the impact of different solutions

Provide Extra Support for Students Who Need It

The **Science and Engineering Practices Online Handbook** will help students achieve a higher level of understanding and skill as they build their experience applying the Science and Engineering Practices of the NGSS.

EDUCATION LEADERS YOU CAN TRUST

Dr. Mike Passow taught 44 years in middle school, high school, and college classrooms and continues to provide professional development for science teachers. He is the founder and organizer of the Earth2Class Workshops for Teachers at the Lamont-Doherty Earth Observatory of Columbia University and served multiple terms as President of the National Earth Science Teachers Association and National Association of Geoscience Teachers-Eastern Section.

DR. MIKE PASSOW

During **Dr. Cary Sneider**'s teaching career and nearly three decades at the Lawrence Hall of Science in Berkeley, California, he developed skills in curriculum development and teacher education. He was a writing team leader for the NGSS and has been instrumental in ensuring *HMH Science Dimensions* meets the high expectations of the NGSS and provides an effective three-dimensional learning experience for all students.

DR. CARY SNEIDER

CONTINUE YOUR EXPLORATION

Careers in Science

Volcanologist

Volcanology is the study of volcanoes: volcanic landforms, volcanic rocks, and eruption processes. Many volcanologists are employed by federal and state governments to monitor active volcanoes. Others work as researchers and professors at universities.

Like other scientists, volcanologists **ask questions**, like *How does magma move underground? When will Yellowstone erupt again?* They **plan and carry out investigations** to make observations and collect data about active and extinct volcanoes in the field and in the lab; and **analyze and interpret data** collected using tools like temperature probes, gas meters, and seismographs. Volcanologists **make and use models** of volcanoes to describe the physical structure of the interior of a volcano, and **use math** to analyze their data and make predictions about eruptions. Finally and very importantly, volcanologists **communicate** their observations, analyses, and conclusions in volcano alert notifications, government reports, scientific journals, conferences, books, websites, films, and classes.

There are several different fields of volcanology. **Physical volcanologists** use simple tools like compasses and rock hammers as well as more complicated tools like gas samplers and thermal imaging cameras to map volcanic landforms and understand the processes that form them.

Geophysicists who work in volcanology use seismometers to understand how magma is moving underground and to predict when a volcano will erupt, gravity-meters to map structures underground, and magnetometers to identify and date different lava flows.

FIGURE 26

Collaborate With a partner, write a scientific question that a volcanologist might try to answer. What fields of volcanology would be involved? What tools would he or she need in an investigation to try to answer this question?

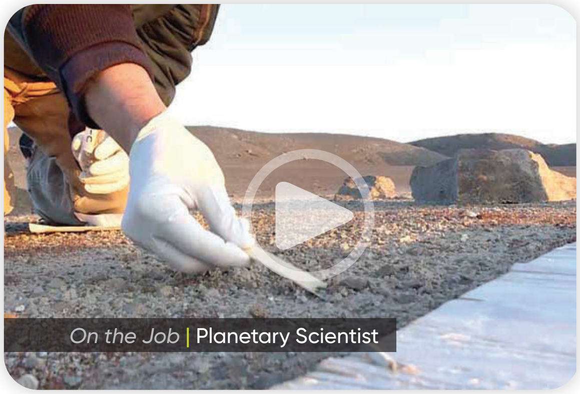
Language Arts Connection Choose a phenomenon related to volcanoes that you would like to investigate. Construct a plan for how you could investigate the phenomenon as well as how you would communicate your finding

HUMAN BOTTLENECK EVENT | HUMAN RESPONSE TO DISASTERS | VOLCANOLOGIST | Go online to choose one of these other paths.

19 Unit 6 Plate Tectonics

Inspire Students to Consider STEM Careers

- Each lesson includes a **Continue Your Exploration** section featuring diverse people in **Careers in Science**. These real-world examples expose students to the variety of careers in the STEM field and spark their curiosity.
- Additionally, all HMH high school science offerings include **CliffsNotes® On the Job STEM** videos that profile STEM careers in today's fastest-growing industries.



On the Job STEM video

Let Students Show What They Know

For the first time ever, science standards now include specific measurable learning outcomes. These **Performance Expectations** (PEs) guide test developers and teachers in understanding how to measure student learning. *HMH Science Dimensions Earth & Space Science* offers flexible assessment tools in a variety of formats to help you assess both formative and summative student learning according to the NGSS.

UNIT PERFORMANCE TASK

Explaining the Abundance of Elements

The table presents data about the most abundant elements in the Milky Way galaxy. Based on what you have learned about the way stars produce elements over their life cycle, develop a claim supported by evidence to explain why these elements are the most abundant.

1. STATE A CLAIM

Based on what you know now, draft a preliminary claim that explains the relationship between stars and the most common elements. Record any questions you have, and list any information you will need to refine and support your claim.

2. GATHER EVIDENCE

Use Internet or library resources to investigate the details of the formation of elements through a star's life cycle. Consider the following questions to guide your research:

- What are the most common fusion processes that take place in stars with masses similar to that of the sun?
- What other fusion processes take place in more massive stars?
- Why are there no elements with atomic numbers greater than 26 on the list?

3. ANALYZE DATA

Use the evidence that you have gathered to revise and refine your original claim as necessary. Then construct your argument, using reasoning to explain how your evidence connects to or supports your claim.

4. COMMUNICATE

Prepare a written presentation of your argument in one or more well-developed paragraphs. You may choose to incorporate diagrams or other visuals in support of your argument, but be sure that your text clearly references them and points out their significance.

FIGURE 6: Ten Most Abundant Elements in the Milky Way Galaxy

Element	Atomic number	Mass fraction (parts per million)
Hydrogen	1	739,000
Helium	2	240,000
Oxygen	8	10,400
Carbon	6	4,600
Neon	10	1,340
Iron	26	1,090
Nitrogen	7	960
Silicon	14	650
Magnesium	12	580
Sulfur	16	440

Source: Ken Croswell, *Alchemy of the Heavens*

CHECK YOUR WORK

A well-crafted argument should meet the following criteria:

- The claim is clearly stated and can be supported by evidence.
- The evidence is empirical, relevant to the claim, and sufficient to support it.
- The reasoning is logical, uses scientific principles to connect the evidence to the claim, and contains no logical flaws or fallacies.

Address Scientific Practices with Authentic Performance Assessments

HMH Science Dimensions Earth & Space Science **Performance-Based Assessments** are hands-on investigations, experiments, and engineering activities that allow teachers to assess the NGSS Science and Engineering Practices while students make connections across PEs.

STUDENT SCIENTISTS AND ENGINEERS

The spirit of the NGSS encourages student-driven exploration. To this end, *HMH Science Dimensions Earth & Space Science* labs and activities prompt students to generate testable questions and work collaboratively to develop their own explanations for scientific phenomena.

Assess on All Dimensions

Formal assessment questions are aligned to multiple dimensions, and unique **3D Evaluation Rubrics** allow teachers to:

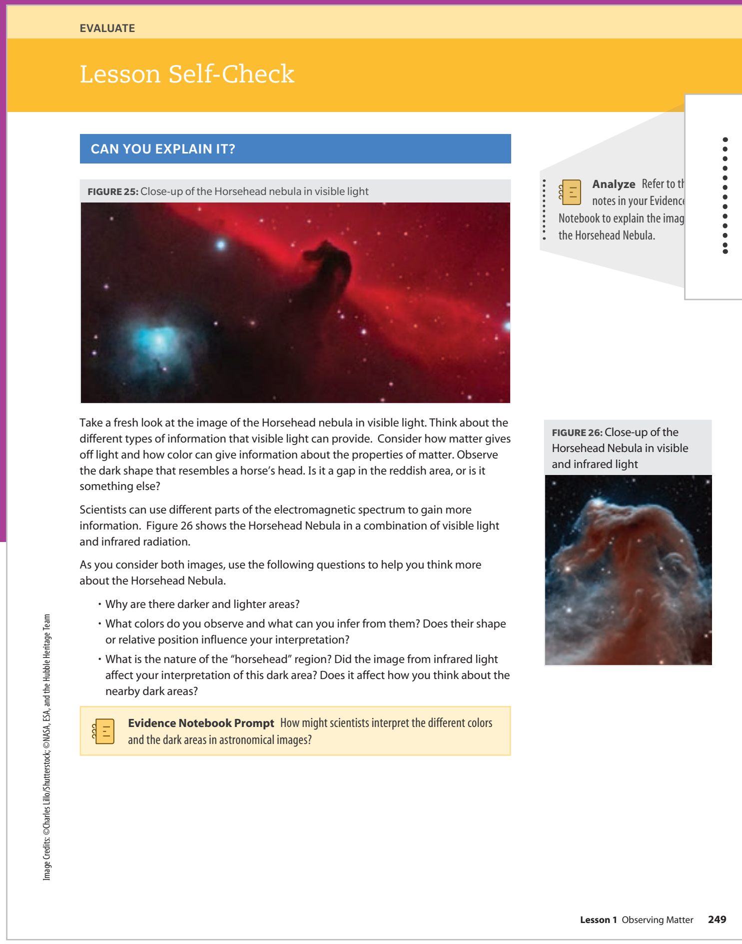
- Evaluate open-ended student responses
- Identify the underlying cause of student misunderstanding
- Target remediation where it is most needed

Performance Task Scoring Rubric

Points	Criteria
	clearly and accurately describes how polar ice changes in the course of a Martian year
	claim accurately explains causes of the patterns
	images reinforce the pattern described
	argument shows clear connections between the claim and the patterns observed

3D Item Analysis	7	8	9	10	11	12	13	14
SEP Engaging in Argument from Evidence				•	•	•	•	•
SEP Developing and Using Models	•	•	•					
DCI Earth and the Solar System	•	•	•		•			
DCI Earth Materials and Systems				•			•	•
DCI Weather and Climate					•		•	•
CCC Cause and Effect				•	•	•	•	•
CCC Stability and Change					•	•	•	
CCC Scale, Proportion, and Quantity	•	•	•					

Assessments that build on student learning processes



EVALUATE

Lesson Self-Check

CAN YOU EXPLAIN IT?

FIGURE 25: Close-up of the Horsehead nebula in visible light

Take a fresh look at the image of the Horsehead nebula in visible light. Think about the different types of information that visible light can provide. Consider how matter gives off light and how color can give information about the properties of matter. Observe the dark shape that resembles a horse's head. Is it a gap in the reddish area, or is it something else?

Scientists can use different parts of the electromagnetic spectrum to gain more information. Figure 26 shows the Horsehead Nebula in a combination of visible light and infrared radiation.

As you consider both images, use the following questions to help you think more about the Horsehead Nebula.

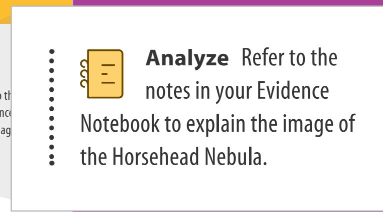
- Why are there darker and lighter areas?
- What colors do you observe and what can you infer from them? Does their shape or relative position influence your interpretation?
- What is the nature of the "horsehead" region? Did the image from infrared light affect your interpretation of this dark area? Does it affect how you think about the nearby dark areas?

Evidence Notebook Prompt How might scientists interpret the different colors and the dark areas in astronomical images?

FIGURE 26: Close-up of the Horsehead Nebula in visible and infrared light

Image Credits: ©Charles Lillo/Shutterstock; ©NASA, ESA, and the Hubble Heritage Team

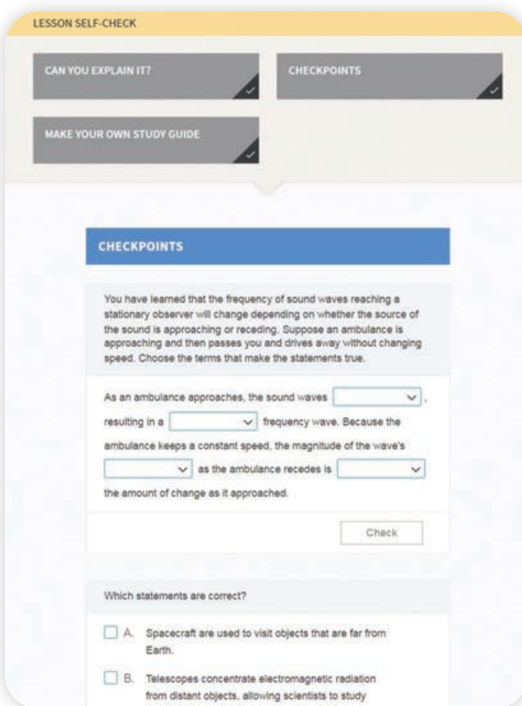
Lesson 1 Observing Matter 249



Analyze Refer to the notes in your Evidence Notebook to explain the image of the Horsehead Nebula.

Reflect on Evidence Gathered

The **Lesson Self-Check** encourages students to reflect on the evidence they gathered throughout the lesson. They have another chance to respond to the investigative phenomenon or central question of the lesson with open-ended response questions.



LESSON SELF-CHECK

CAN YOU EXPLAIN IT?

CHECKPOINTS

MAKE YOUR OWN STUDY GUIDE

CHECKPOINTS

You have learned that the frequency of sound waves reaching a stationary observer will change depending on whether the source of the sound is approaching or receding. Suppose an ambulance is approaching and then passes you and drives away without changing speed. Choose the terms that make the statements true.

As an ambulance approaches, the sound waves [ ], resulting in a [ ] frequency wave. Because the ambulance keeps a constant speed, the magnitude of the wave's [ ] as the ambulance recedes is [ ] the amount of change as it approached.

Check

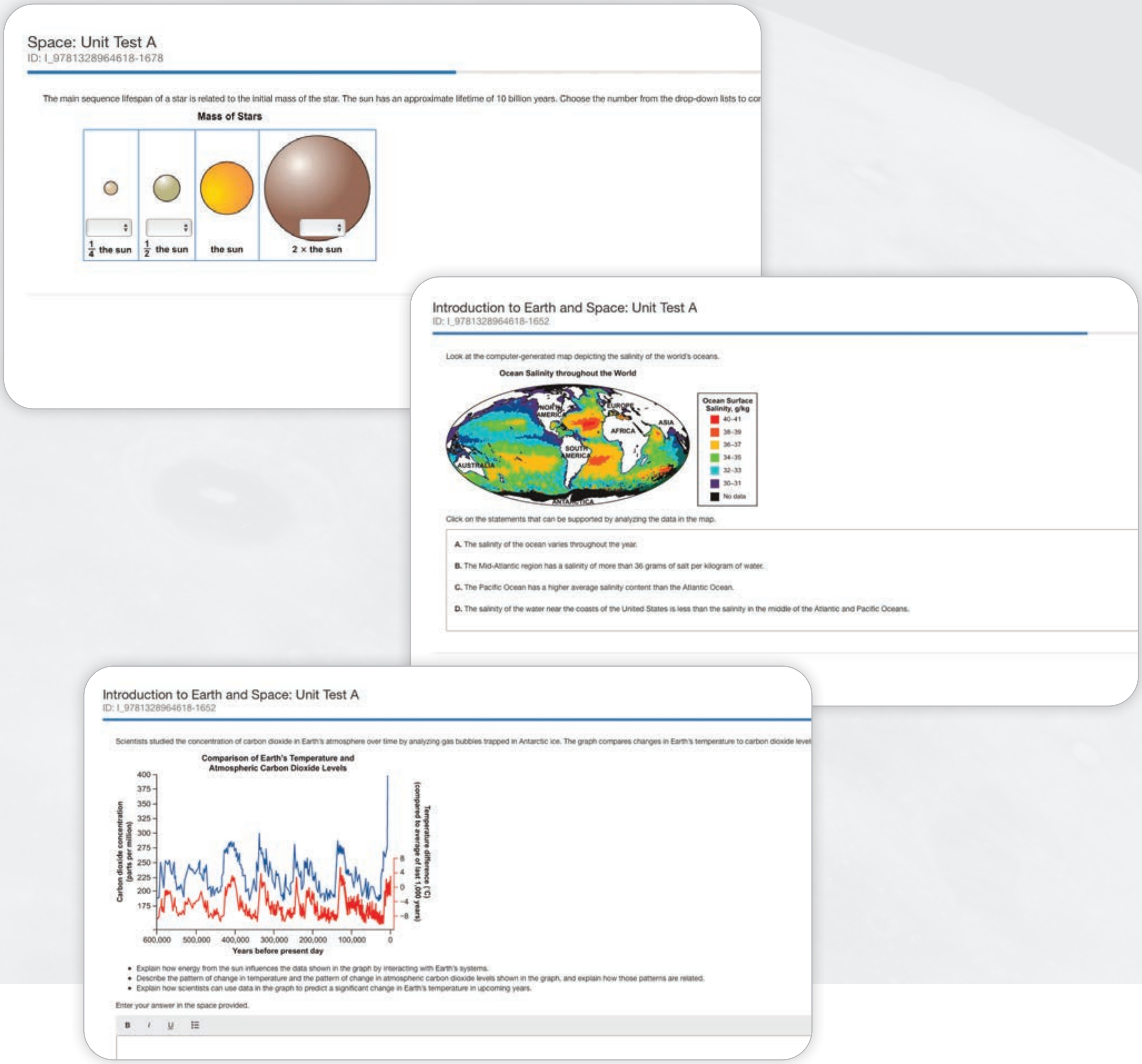
Which statements are correct?

A. Spacecraft are used to visit objects that are far from Earth.

B. Telescopes concentrate electromagnetic radiation from distant objects, allowing scientists to study

Prepare for High-Stakes Tests

- Technology-enhanced assessment items (multi-select, drag and drop, etc.) prepare your students for modern, computer-based, high-stakes tests.
- Rigorous Mid-Year and End-of-Year benchmarks help you ensure that your students fully understand concepts and perform with success.
- Leveled benchmark tests help make the assessment accessible for all of your students.



Scaffold to Higher-Level Thinking Skills

Formal assessments build in complexity:

- **Unit Pretests** make sure students have the basic knowledge they need for lessons.
- **Lesson Quizzes** provide a quick check that students are understanding the 3D concepts.
- **Unit Tests** check for understanding and challenge students to apply what they've learned.
- **Mid-Year** and **End-of-Year Benchmark Tests** help ensure students are on track to achieve the PEs.
- **Performance-Based Assessments** combine hands-on engineering with knowledge application skills for true measurement of progress towards the PEs of the NGSS.

Engage with Meaningful Technology

HMH Science Dimensions Earth & Space Science leverages the advantages of technology while prioritizing a student-centered learning model. Students can view videos and animations, interact with instructional images and text, enter responses, pursue their intellectual interests by choosing lesson paths, and enjoy simulation-based learning. All of these features help you maintain an integrated, three-dimensional approach to learning science.

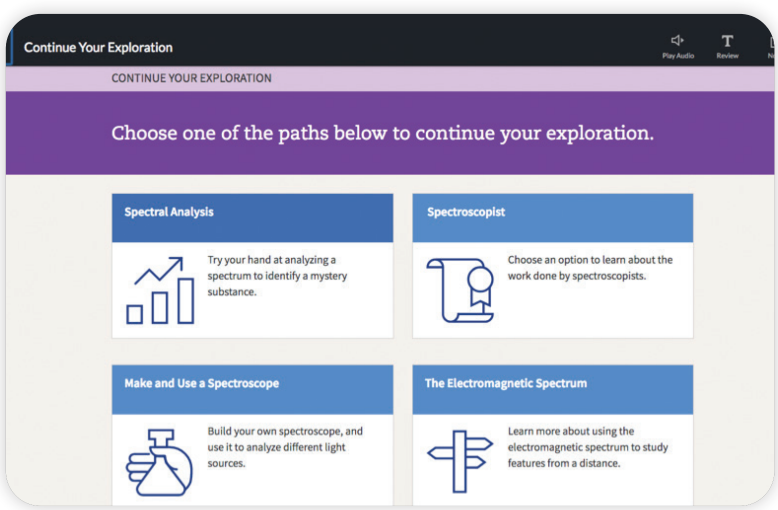
Immersive Digital Curriculum

Online lessons are enriched above and beyond the print lessons for powerful differentiation options. The digital lessons include:

- Educational videos
- Learning interactivities
- Places to save typewritten and technology-enhanced student work
- Clickable vocabulary with pop-up definitions at point-of-use

Maximize Student Choice

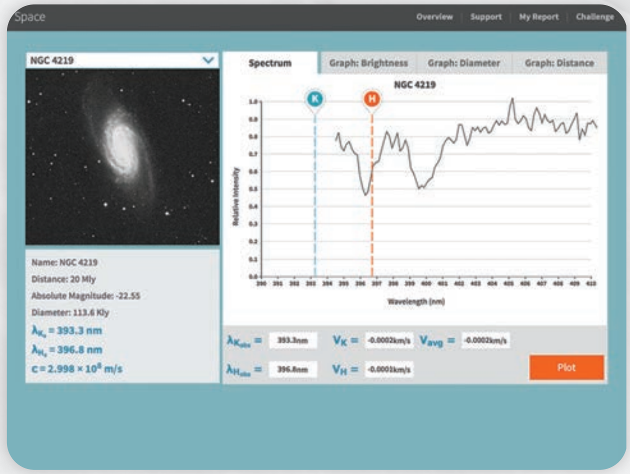
The **Continue Your Exploration** feature at the end of each lesson maximizes the opportunity for students to elaborate further on what they have learned so far. While online, students can dive deep into topics of their choice to learn more and to create stronger, more personal links to their learning.

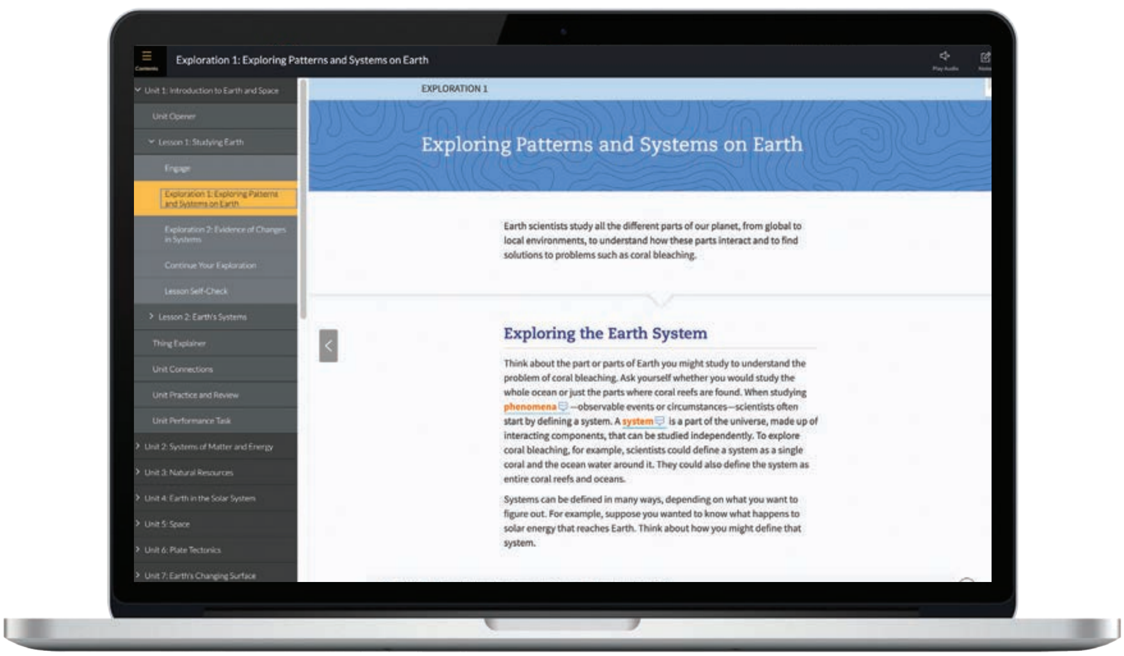


DEEPEN UNDERSTANDING WITH OPEN-ENDED SIMULATIONS

Unique **You Solve It!** open-ended simulations allow students to:

- Adjust experiment inputs
- Explore multiple answers to a problem
- Reset the simulation and enter new inputs
- Develop claims, gather evidence, and formulate explanations to outputs using reasoning to defend their answers





The Ultimate Online and Offline Program Experience

- Teachers can look forward to accessing *HMH Science Dimensions* on *Ed*®, the HMH learning platform. *Ed* combines the best of technology, HMH content, and instruction to personalize the teaching and learning experience for every teacher and student. Subscriptions to *HMH Science Dimensions* automatically include future enhancements to *Ed*'s resources and features.
- Additionally, program content can be accessed offline, allowing for maximum compatibility in 1:1 or in Bring Your Own Device learning environments and with the wide variety of technology that students have at home.
- If you would like to explore *HMH Science Dimensions Earth & Space Science* digitally you can request access by visiting **hmhco.com/ScienceDimensions.**

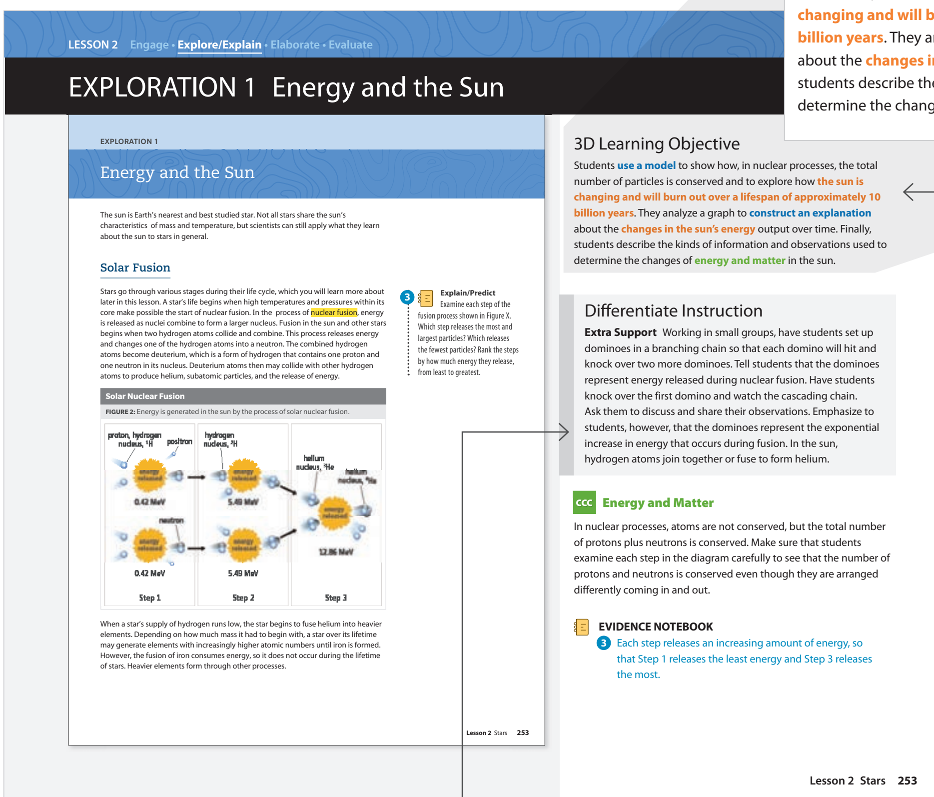
HMH Ed™

Three-Dimensional Learning Made Simple

HMH Science Dimensions Earth & Space Science expertly weaves the Three Dimensions of Learning into each lesson in order to meet the PEs. This integrated approach takes the burden off you while ensuring a high-quality 3D learning experience for your students.

3D Learning Objective

Students **use a model** to show how, in nuclear processes, the total number of particles is conserved and to explore how **the sun is changing and will burn out over a lifespan of approximately 10 billion years**. They analyze a graph to **construct an explanation** about the **changes in the sun's energy** output over time. Finally, students describe the kinds of information and observations used to determine the changes of **energy and matter** in the sun.



LESSON 2 Engage • **Explore/Explain** • Elaborate • Evaluate

EXPLORATION 1 Energy and the Sun

EXPLORATION 1

Energy and the Sun

The sun is Earth's nearest and best studied star. Not all stars share the sun's characteristics of mass and temperature, but scientists can still apply what they learn about the sun to stars in general.

Solar Fusion

Stars go through various stages during their life cycle, which you will learn more about later in this lesson. A star's life begins when high temperatures and pressures within its core make possible the start of nuclear fusion. In the process of nuclear fusion, energy is released as nuclei combine to form a larger nucleus. Fusion in the sun and other stars begins when two hydrogen atoms collide and combine. This process releases energy and changes one of the hydrogen atoms into a neutron. The combined hydrogen atoms become deuterium, which is a form of hydrogen that contains one proton and one neutron in its nucleus. Deuterium atoms then may collide with other hydrogen atoms to produce helium, subatomic particles, and the release of energy.

3 Explain/Predict Examine each step of the fusion process shown in Figure X. Which step releases the most and largest particles? Which releases the fewest particles? Rank the steps by how much energy they release, from least to greatest.

Solar Nuclear Fusion

FIGURE 2: Energy is generated in the sun by the process of solar nuclear fusion.

When a star's supply of hydrogen runs low, the star begins to fuse helium into heavier elements. Depending on how much mass it had to begin with, a star over its lifetime may generate elements with increasingly higher atomic numbers until iron is formed. However, the fusion of iron consumes energy, so it does not occur during the lifetime of stars. Heavier elements form through other processes.

Lesson 2 Stars 253

3D Learning Objective

Students use a model to show how, in nuclear processes, the total number of particles is conserved and to explore how the sun is changing and will burn out over a lifespan of approximately 10 billion years. They analyze a graph to construct an explanation about the changes in the sun's energy output over time. Finally, students describe the kinds of information and observations used to determine the changes of energy and matter in the sun.

Differentiate Instruction

Extra Support Working in small groups, have students set up dominoes in a branching chain so that each domino will hit and knock over two more dominoes. Tell students that the dominoes represent energy released during nuclear fusion. Have students knock over the first domino and watch the cascading chain. Ask them to discuss and share their observations. Emphasize to students, however, that the dominoes represent the exponential increase in energy that occurs during fusion. In the sun, hydrogen atoms join together or fuse to form helium.

CCC **Energy and Matter**

In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. Make sure that students examine each step in the diagram carefully to see that the number of protons and neutrons is conserved even though they are arranged differently coming in and out.

EVIDENCE NOTEBOOK

3 Each step releases an increasing amount of energy, so that Step 1 releases the least energy and Step 3 releases the most.

Lesson 2 Stars 253

3D Learning Objectives

Each lesson has unique, interrelated **3D Learning Objectives**:

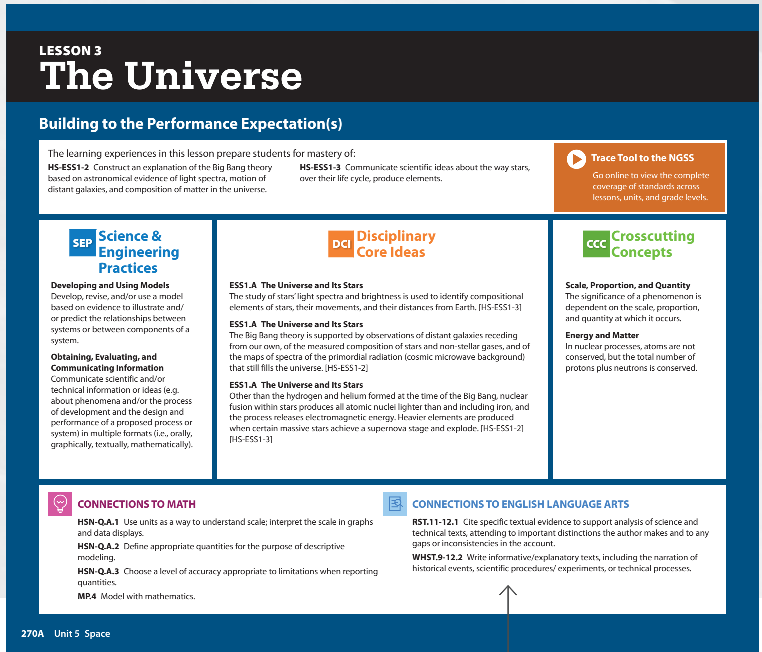
- The color-coding indicates the SEP, CCC, and DCI coverage in the lesson.
- The description shows teachers how the 3D Learning Objectives work together in the lesson to progress towards the PEs

Enrich the Learning Experience

Additional Collaboration, Differentiated Instruction, Formative Assessment, and Claims, Evidence, and Reasoning suggestions provide a wealth of support and resources.

CLEARLY LABELED NGSS REFERENCES

The **NGSS labeling** in the Teacher Edition clearly identifies all the PEs, SEPs, DCIs, and CCCs of the NGSS, including the math and ELA connections. This helps educators identify the standards that are being covered in any given lesson.



LESSON 3

The Universe

Building to the Performance Expectation(s)

The learning experiences in this lesson prepare students for mastery of:

HS-ESS1-2 Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements.

Trace Tool to the NGSS
Go online to view the complete coverage of standards across lessons, units, and grade levels.

SEP Science & Engineering Practices

Developing and Using Models
Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Obtaining, Evaluating, and Communicating Information
Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

DCI Disciplinary Core Ideas

ESS1.A The Universe and Its Stars
The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. [HS-ESS1-3]

ESS1.A The Universe and Its Stars
The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. [HS-ESS1-2]

ESS1.A The Universe and Its Stars
Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. [HS-ESS1-2] [HS-ESS1-3]

CCC Crosscutting Concepts

Scale, Proportion, and Quantity
The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Energy and Matter
In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

CONNECTIONS TO MATH

HSN-Q.A.1 Use units as a way to understand scale; interpret the scale in graphs and data displays.
HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.
HSN-Q.A.3 Choose a level of accuracy appropriate to limitations when reporting quantities.
MP.4 Model with mathematics.

CONNECTIONS TO ENGLISH LANGUAGE ARTS

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

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Incorporate English Language Arts and Math Connections

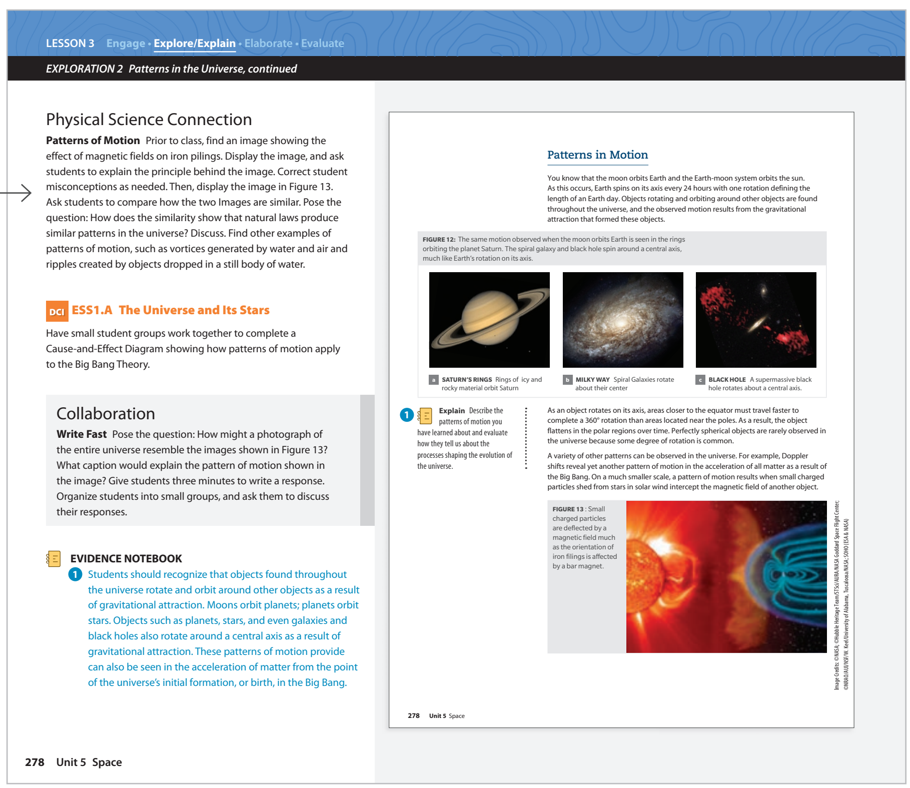
Strong math and reading skills are essential to ensuring STEM learning and science literacy. *HMH Science Dimensions* offers Common Core **Math and ELA connections** throughout the curriculum.

Utilize the 5E Model

The Teacher Edition (online and print) is organized around the familiar **5E instructional model**. This helps to ensure a seamless transition and provide a solid foundation upon which to build an NGSS curriculum.

Cross-Curricular Integration

The Teacher Edition provides connections to other science disciplines, like physical science and chemistry, within each lesson. Additionally, at the unit level, **Unit Connections** provide ideas for cross-curricular projects in engineering, social studies, computer science, and more.



LESSON 3 Engage • **Explore/Explain** • Elaborate • Evaluate

EXPLORATION 2 Patterns in the Universe, continued

Physical Science Connection

Patterns of Motion Prior to class, find an image showing the effect of magnetic fields on iron pilings. Display the image, and ask students to explain the principle behind the image. Correct student misconceptions as needed. Then, display the image in Figure 13. Ask students to compare how the two Images are similar. Pose the question: How does the similarity show that natural laws produce similar patterns in the universe? Discuss. Find other examples of patterns of motion, such as vortices generated by water and air and ripples created by objects dropped in a still body of water.

DCI ESS1.A The Universe and Its Stars

Have small student groups work together to complete a Cause-and-Effect Diagram showing how patterns of motion apply to the Big Bang Theory.

Collaboration

Write Fast Pose the question: How might a photograph of the entire universe resemble the images shown in Figure 13? What caption would explain the pattern of motion shown in the image? Give students three minutes to write a response. Organize students into small groups, and ask them to discuss their responses.

EVIDENCE NOTEBOOK

1 Students should recognize that objects found throughout the universe rotate and orbit around other objects as a result of gravitational attraction. Moons orbit planets; planets orbit stars. Objects such as planets, stars, and even galaxies and black holes also rotate around a central axis as a result of gravitational attraction. These patterns of motion provide can also be seen in the acceleration of matter from the point of the universe's initial formation, or birth, in the Big Bang.

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Patterns in Motion

You know that the moon orbits Earth and the Earth-moon system orbits the sun. As this occurs, Earth spins on its axis every 24 hours with one rotation defining the length of an Earth day. Objects rotating and orbiting around other objects are found throughout the universe, and the observed motion results from the gravitational attraction that formed these objects.

FIGURE 12: The same motion observed when the moon orbits Earth is seen in the rings orbiting the planet Saturn. The spiral galaxy and black hole spin around a central axis, much like Earth's rotation on its axis.

a **SATURN'S RINGS** Rings of icy and rocky material orbit Saturn
b **MILKY WAY** Spiral Galaxies rotate about their center
c **BLACK HOLE** A supermassive black hole rotates about a central axis.

1 **Explain** Describe the patterns of motion you have learned about and evaluate how they tell us about the processes shaping the evolution of the universe.

As an object rotates on its axis, areas closer to the equator must travel faster to complete a 360° rotation than areas located near the poles. As a result, the object flattens in the polar regions over time. Perfectly spherical objects are rarely observed in the universe because some degree of rotation is common.

A variety of other patterns can be observed in the universe. For example, Doppler shifts reveal yet another pattern of motion in the acceleration of all matter as a result of the Big Bang. On a much smaller scale, a pattern of motion results when small charged particles shed from stars in solar wind intercept the magnetic field of another object.

FIGURE 13: Small charged particles are deflected by a magnetic field much as the orientation of iron filings is affected by a bar magnet.

Image Credits: ©NASA; ©Hubble Heritage Team/STScI/AURA/NASA Goddard Space Flight Center; ©NRAO/AUI/NSF/W. Keel/University of Alabama, Tuscaloosa/NASA; SOHO (ESA & NASA)

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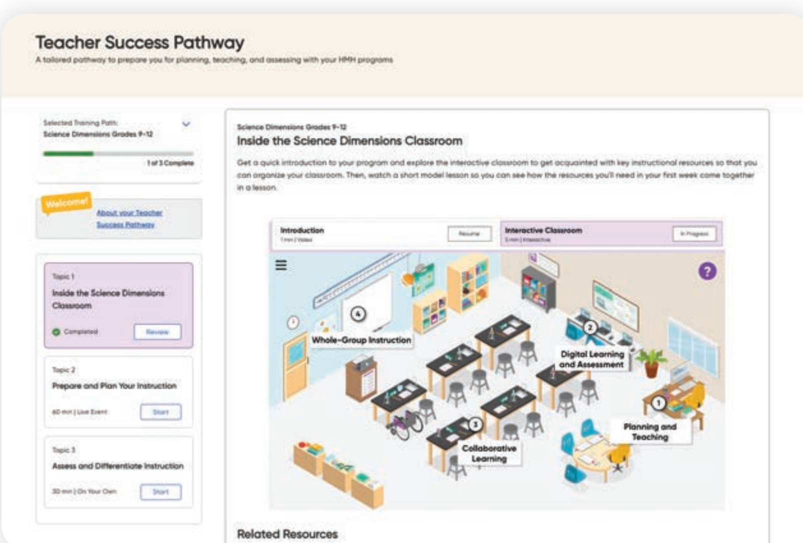

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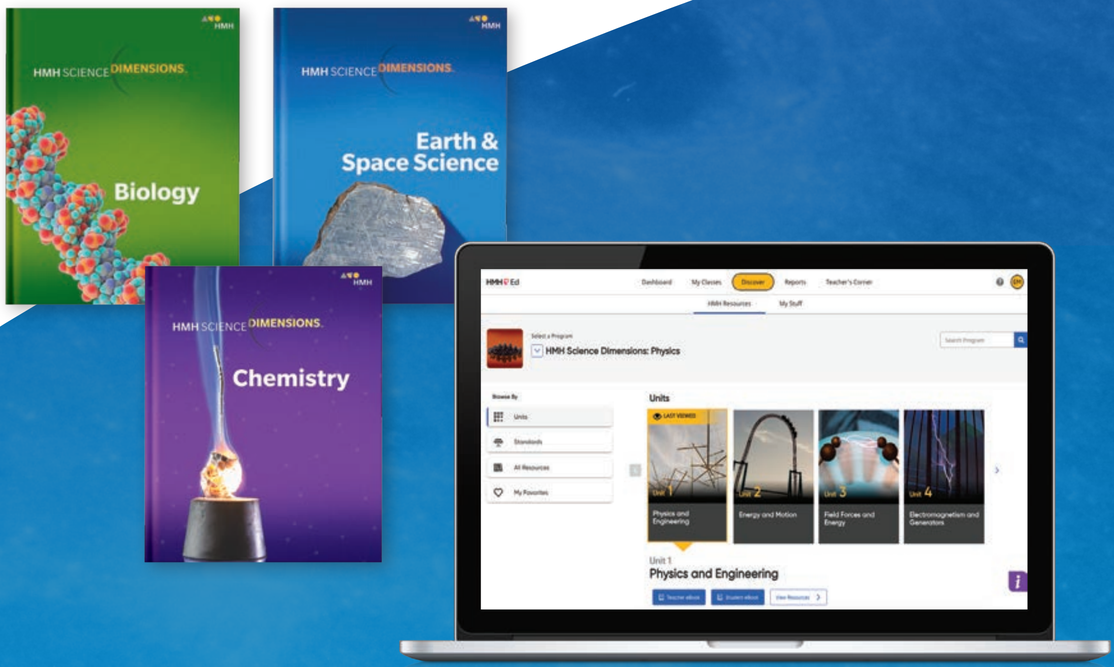

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