PhD SCIENCE®

Implementation Guide

Levels K–5

GREAT MINDS™

PhD SCIENCE®

Implementation Guide

Great Minds® is the creator of *Eureka Math*®, *Eureka Math²*®, *Wit & Wisdom*®, and *PhD Science*®.

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Contents

Introduction

The Implementation Guide is a teacher resource that explains the philosophy and curriculum design of *PhD Science*®. It also provides additional resources to help make instruction more efficient and effective.

Foundations

PhD Science is an exemplary new science program from Great Minds PBC, the creators of *Eureka Math*® and *Wit & Wisdom*®. Based on the Next Generation Science Standards (NGSS) and created by our team of teacher–writers and subject matter experts, this innovative curriculum inspires students to wonder about the world and empowers them to make sense of it.

Kindergarten through Level 5 are the first completed levels of what will become a full Kindergarten through Level 8 science curriculum. Each level consists of four modules that prepare students for success in elementary school science and beyond.

Great Minds believes that every child is capable of greatness. The mission of *PhD Science* is to help teachers provide their students with a science education that is as limitless as science itself. To achieve this goal, students **rigorously engage** in learning that builds their **coherent** understanding of scientific **knowledge**.

- **Knowledge:** Throughout each *PhD Science* module, students engage with all three dimensions of the NGSS and integrate those dimensions to build enduring scientific understanding and competence. They skillfully apply Science and Engineering Practices (SEPs) to construct understanding of Disciplinary Core Ideas (DCIs) through the lens of Crosscutting Concepts (CCs). Across modules and levels, students revisit fundamental science concepts, deepening their understanding of those concepts and applying them to make sense of new phenomena.
- **Coherence:** Each module weaves a storyline through which students make sense of compelling phenomena. Each lesson builds on previous lessons, allowing students to reflect on their learning, generate new questions, and investigate related topics. Throughout a module, students periodically connect their learning to make sense of an anchor phenomenon. As students integrate and apply new knowledge, coherence extends across modules, levels, and even content areas.
- **Rigorous Engagement:** Students actively engage in a learning cycle of asking questions and sharing initial ideas about phenomena, investigating those questions, developing evidence-based explanations, and transferring their knowledge to explain different phenomena in new contexts. Teachers facilitate learning, but students own it. Supported by differentiation strategies, students engage with rigorous content through hands-on investigations, collaborative conversations, and analysis of authentic texts and media.

Research in Action

PhD Science helps teachers put research-based best practices into action.

Research Says	Students Need	*PhD Science* Responds
A scientifically literate individual "can ask, find, or determine answers to questions derived from curiosity about everyday experiences"; "describe, explain, and predict natural phenomena"; and "read with understanding articles about science in the popular press" (NRC 1996, 22). "The study of science and engineering should produce a sense of the process of argument necessary for advancing and defending a new idea or an explanation of a phenomenon and the norms for conducting such arguments. In that spirit, students should argue for the explanations they construct, defend their interpretations of the associated data, and advocate for the designs they propose" (NRC 2012, 73).	Students need to be free to follow their curiosity to better understand the world around them. Students need to know how to participate in scientific discourse, ask challenging questions with clarity and precision, and respond to criticism. Students need to make claims, support their claims with evidence, elaborate on their ideas, and challenge the claims of others.	Great Minds believes that student curiosity should inspire learning. Modules are driven by compelling, carefully chosen, knowledge-rich phenomena that lead to questions about the world. Students create a driving question board that they update as they find answers to their existing questions or when new questions arise. The curriculum also provides many opportunities for students to engage in scientific discourse. In each lesson, students make observations, develop claims, and defend their claims with evidence. Science Challenges and Engineering Challenges allow students to work with peers to answer questions or solve problems and present their findings to the class. A Socratic Seminar at the end of each module gives students an opportunity to synthesize their learning, discuss their ideas, and present evidence to support or refute claims.
"Misconceptions about the processes of science tend to occur when the processes become ends in themselves, divorced from core concepts of science. For students to learn how to 'do' science, they need to understand the roles of observation, imagination, and reasoning" (Allen 2006, 7).	Students need hands-on experiences that require the practical application of scientific processes. Students need time to observe, imagine, and reason.	*PhD Science* introduces students to new concepts through engaging activities that allow them first to observe and wonder and then to investigate and deeply understand phenomena. Students are given opportunities to develop student-driven investigations and apply scientific processes in new contexts through Science Challenges or Engineering Challenges.

Research Says	Students Need	*PhD Science* Responds
"As the *Framework* states, 'knowledge and practice must be intertwined in designing learning experiences in K–12 science education.' Engaging solely in the practices without including disciplinary core ideas and crosscutting concepts is insufficient because each of these concepts is required to make sense of phenomena" (National Science Teaching Association [NSTA] 2018b, 1). Some educators do not think that current science curricula incorporate the standards deeply or effectively enough. Part of this problem stems from the way standards have historically been written without consideration of connections across topics and grade levels (Allen 2006).	Students need learning experiences that allow them to see connections between scientific ideas, concepts, and practices. Students need learning experiences in a context that helps them make sense of phenomena and the world. Students need a coherent approach to studying science with clear connections among concepts and across levels.	Great Minds is committed to presenting science content deeply, connecting learning within and between levels with carefully chosen, interwoven phenomena, often introduced with stories and the history of science. The curriculum fosters three-dimensional learning and assessment, highlighting for teachers the opportunities for each at the beginning of each lesson set and in notes within lessons. Through this three-dimensional approach, students begin to see connections among scientific ideas, concepts, and practices as they apply their knowledge to understand phenomena and the world.
"Many elementary school teachers, the proverbial jacks-of-all-trades, face a trio of issues when it comes to teaching science: they don't like science, they don't feel confident in their knowledge of science, and they don't know how to teach science effectively" (Allen 2006, 1). Science is one of the first topics elementary teachers cut during the school day because of the need to focus on subjects such as language arts and mathematics (Allen 2006).	Students need time to study science with teachers who present it effectively. Students need opportunities to practice English language arts skills, mathematics skills, and skills from other content areas in a scientific context.	*PhD Science* supports teachers with lesson notes that contain relevant background knowledge and suggested questions to guide student discussions. Core texts, an important component of most modules, allow teachers to present relatable content and inspire student learning through compelling stories. Connections to other content areas in lessons signal opportunities for students to practice grade-appropriate English language arts skills, mathematics skills, and skills from other content areas.

Research Says	Students Need	*PhD Science* Responds
"Assessment must be aligned with— a. what is of value, i.e., the problem-solving model of instruction: concept application, inquiry, and process skills. b. the curricular objective and instructional mode. c. the purpose for which it was intended: grading, diagnosis, student and/or parent feedback, or program evaluation" (NSTA 2018a).	Students need meaningful and contextual assessments that allow them to apply scientific concepts to different phenomena. Students need purposeful assessments, whether diagnostic, formative, or summative.	*PhD Science* offers several types of assessment in each module. Checks for Understanding in each lesson guide teachers as they evaluate student progress throughout the lesson set. Conceptual Checkpoints periodically gauge student understanding of important concepts in unfamiliar contexts before students move forward in the module. Science Challenges and Engineering Challenges allow students to apply learning in both familiar and unfamiliar contexts. End-of-module lessons have three components: First, students participate in a Socratic Seminar to discuss and synthesize module learning; next, a summative individual assessment gives students an opportunity to demonstrate mastery of knowledge and skills they acquired throughout the module; finally, students evaluate their own learning.

Product Components

TEACHER EDITION

Module Overview and Appendices

The Teacher Edition begins with a module overview, which contains an introduction to the anchor phenomenon, an explanation of how the module lessons address the phenomenon, a module map, focus standards, key terms, information about the preparation of materials, safety considerations, a summary of knowledge and skills built across levels, and professional resources for teachers.

Each module contains approximately 25 to 30 lessons organized into two to four concepts that help students make sense of an anchor phenomenon. Each concept contains lesson sets that develop key conceptual understandings.

At the end of each module's Teacher Edition, appendices provide support for teachers before and during instruction.

- **Appendix A: Module Resources**—a set of lesson-specific resources to aid instruction: full-size photographs, informational texts, investigation procedure sheets, materials preparation, and supplemental information
- **Appendix B: Module Storyline**—a more detailed version of the Module Map section in the Module Overview that summarizes the progression of concepts in the module
- **Appendix C: Module Glossary**—level-appropriate definitions for new terms in the module and the lesson in which the definition appears
- **Appendix D: Domain-Specific Words, General Academic Words, and Spanish Cognates**—a list of key terms in the module and their Spanish cognates to support English language development

Lesson Sets

Lesson sets consist of 35-minute lessons in Kindergarten through Level 2 and 45-minute lessons in Levels 3 through 5. The lessons in each lesson set are grouped by specific phenomena. This structure and the pacing suggestions in each lesson's Agenda give students flexibility to explore phenomena and analyze their findings to arrive at conceptual understandings.

All lesson sets have a Prepare section, which contains the following information:

- **Opening Paragraph:** a brief introduction to the lesson set and its three-dimensional learning
- **Focus Question:** a question that guides learning throughout the concept (remains the same throughout a concept)
- **Phenomenon Question:** a question that guides learning throughout the lesson set (changes with each lesson set)
- **Knowledge Statement:** a statement that reflects the scientific understanding students will develop during a lesson set (to guide teachers, not to post for students)
- **Objectives:** learning outcomes for each lesson (to guide teachers, not to post for students)
- **Standards Addressed:** a summary of the focus Performance Expectation(s), SEPs, DCIs, and CCs the lesson set addresses
- **Materials:** a list of materials needed for each lesson, including necessary preparation (includes optional materials and substitutions where applicable)

Each lesson is organized into these sections:

- **Launch:** the lesson opening, which engages students as they begin thinking about the lesson phenomenon
- **Learn:** the heart of the lesson, during which students develop new knowledge and apply prior knowledge to explore phenomena
- **Land:** the lesson closing, in which students reflect on what they have learned
- **Optional Homework:** suggestions for applying and extending science learning in students' homes and communities (does not occur in every lesson)

Each lesson also contains embedded instructional supports and sidebar notes with additional information for teachers. These notes help teachers deepen their knowledge of science content, pedagogy, and the progression of student learning. The table below describes the notes teachers will encounter throughout the lessons.

Check for Understanding: Evaluation guidance for teachers, including evidence of student understanding and instructional next steps (when applicable)

Conceptual Checkpoint: Conceptual Checkpoint evaluation guidance for teachers, including evidence of student understanding and instructional next steps

Content Area Connection, English: Cross-curricular connections, instructional strategies, or additional activities that align with Common Core State Standards for English Language Arts/Literacy

Content Area Connection, Mathematics: Cross-curricular connections, instructional strategies, or additional activities that align with Common Core State Standards for Mathematics

Content Area Connection, Other: Cross-curricular connections, instructional strategies, or additional activities in other content areas, such as history or art

Differentiation: Differentiation strategies to support all students in meeting the lesson goals

English Language Development: English language development strategies to support all students in meeting the lesson goals

Extension: Additional learning opportunities related to the lesson topic that extend beyond the time allotted for the lesson

Safety Note: Guidance for safety procedures specific to a lesson activity

Spotlight on Three-Dimensional Integration: Explanation of how a lesson activity develops specific SEPs, DCIs, and/or CCs

Teacher Note: Additional educative information for teachers

SCIENCE LOGBOOK

The Science Logbook is a consumable student resource. It enables students to record evidence and to document their learning. In most lessons, students use their logbooks to develop models or record observations, predictions, data analysis, explanations, claims, and other information as they complete scientific tasks.

MATERIALS KITS

PhD Science provides hands-on experiences that enable students to engage in science activities that align with the SEPs. Materials kits that support these experiences are available for purchase through Great Minds and sourced by an external supplier. These specially designed kits contain the supplies needed to implement the *PhD Science* investigations and activities in all four modules of each level. Organized by module, the materials kits arrive in bins that can store reusable materials from year to year. Refill kits are available to replace consumable supplies. Optional safety kits containing goggles and latex-free gloves are also recommended and available for purchase. Each lesson set contains a list of necessary materials and a summary of required materials preparation.

Getting Started

Phenomena

THE *PHD SCIENCE* APPROACH TO PHENOMENA

Scientific phenomena are observable events that can be explained or predicted through scientific understanding. They range from everyday events, such as animals interacting with a tree in the schoolyard, to extraordinary events that challenge our understanding of the world, such as a soccer ball floating on the International Space Station. *PhD Science* is a phenomenon-driven curriculum because powerfully effectual learning in science can only occur with rich context. By carefully selecting and introducing a variety of phenomena, *PhD Science* lays a path for students to reveal enduring knowledge about the world around them.

Web of Phenomena

Each *PhD Science* module includes a web of interrelated phenomena. Phenomena play various roles in instruction, including the following:

- **Anchor phenomenon:** The anchor phenomenon is a rich, multilayered scientific phenomenon that motivates instruction throughout the module. At the beginning of each module, students explore the anchor phenomenon and use their background knowledge to develop an initial anchor model to explain the anchor phenomenon. The anchor model generates questions that drive students to explore the anchor phenomenon and other related phenomena throughout the module. After each concept sequence, students return to the anchor phenomenon to refine their anchor model, deepen their explanations, and distill their understanding of transferable science skills and knowledge. By the end of the module, students apply their skills and knowledge to explain important aspects of the anchor phenomenon and acknowledge unexplained aspects.

- **Supporting phenomena:** Lessons throughout each module focus on supporting phenomena, also known as investigative phenomena. These phenomena relate to some aspect of the anchor phenomenon. Exploration and investigation of these phenomena lead students to reveal key ideas in a coherent storyline. As students connect the ideas revealed through supporting phenomena, they become equipped to apply their knowledge to a variety of contexts, including the anchor phenomenon.

- **Student-generated phenomena:** Throughout each module, students share related phenomena they have experienced in their lives. By connecting students' experiences to the phenomena and concepts presented in the module, teachers gain insight into students' existing conceptions. By reflecting on these phenomena throughout the module, students can refine their ability to use the knowledge they develop in the module to explain the world around them.

- **Phenomenon-driven assessment:** All assessments, including ongoing embedded formative assessments, are centered around explaining phenomena or solving problems that arise from phenomena. This approach helps both teachers and students move away from decontextualized, rote memorization of ideas and toward an inquiry-driven, evidence-based explanation of the world.

From the student perspective, the phenomena in a module are woven together to gradually reveal pieces of the anchor phenomenon. For example, after students learn that the anchor phenomenon in Level 4 Module 3 is elephants sensing distant rainstorms, they share ideas about related phenomena, such as a pet dog "knowing" when someone is at the door before its owner knows. These related phenomena raise questions about a variety of connected science ideas, such as How do structures help us sense the environment? What are we sensing from the environment? and How do we respond when we get information from our environment? To answer these questions, students explore supporting phenomena ranging from animal senses to ocean waves. Exploring these phenomena reveals important scientific concepts that can explain aspects of how elephants sense distant rainstorms and allows students to reflect on the related phenomena they have shared (e.g., whether the phenomena are truly related, how the phenomena may be explained through newly realized ideas). In assessments, students demonstrate their understanding by explaining new phenomena, such as how Helen Keller enjoyed one of Beethoven's symphonies without the sense of hearing. Through such an interconnected web of phenomena, students come to understand how they can apply science knowledge to explain novel phenomena.

Characteristics of Rich Phenomena

PhD Science presents a unique approach to phenomenon-driven instruction by situating scientific phenomena in a cultural context. Students study carefully curated trade texts, artworks, and primary sources that tell the historical and cultural stories surrounding phenomena. They come to see science and engineering as processes of understanding and improving the world in which they live. Rich phenomena engage all learners by offering multiple access points for students' diverse experiences and interests and providing various avenues for questioning and investigation.

To develop this array of interconnected phenomena, *PhD Science* features phenomena with one or more of the following characteristics:

- **Social significance:** Phenomena exhibit enduring significance in diverse cultures and content areas. Stories, art, and primary sources often illustrate the multifaceted nature of these phenomena. For example, in Level 4 Module 2, students raise questions about windmills and energy by exploring two of Piet Mondrian's windmill paintings and the story of young William Kamkwamba building a windmill to generate electricity in Malawi.
- **Classroom relevance:** Phenomena stimulate classroom exploration through demonstrations and investigations that involve the manipulation of variables and encourage hands-on exploration. For example, students mix substances with copper and observe a green patina form on the copper in Level 5 Module 1.
- **Everyday connection:** Phenomena allow students to make connections to their everyday lives and personal experiences. For example, in Level K Module 1, students use their experiences with local weather phenomena, such as typical weather and severe weather events, to help explain how the cliff dwellings at Mesa Verde protected the Ancestral Pueblo people.
- **Historical connection:** Phenomena encourage the study of historical applications, investigations, and explanations that reveal key shifts in human understanding about scientific concepts. By learning about the history of science through primary sources and other documents, students come to see science as a process of inquiry and empirical argument rather than a fixed body of knowledge. For example, in Level 1 Module 4, students learn about an ancient Polynesian system of navigation in which people used observations of the Sun, the Moon, and stars to help them navigate to distant islands.

ACHIEVING THE STANDARDS

To achieve the vision laid out by *A Framework for K–12 Science Instruction* (NRC 2012), students must build knowledge about scientific ideas through the exploration of rich phenomena. This approach represents a key shift away from practices that emphasize rote memorization of discrete facts, terms, and formulas above authentic inquiry and reasoning. However, to achieve this shift, student inquiry must be purposeful and rise from a genuine desire to explain scientific phenomena or to provide solutions to scientific problems. Therefore, each *PhD Science* module focuses on student-generated questions about carefully selected phenomena, allowing students to engage in elements of DCIs by applying SEPs and the lens of CCs.

THE EFFECT OF PHENOMENON-DRIVEN LEARNING

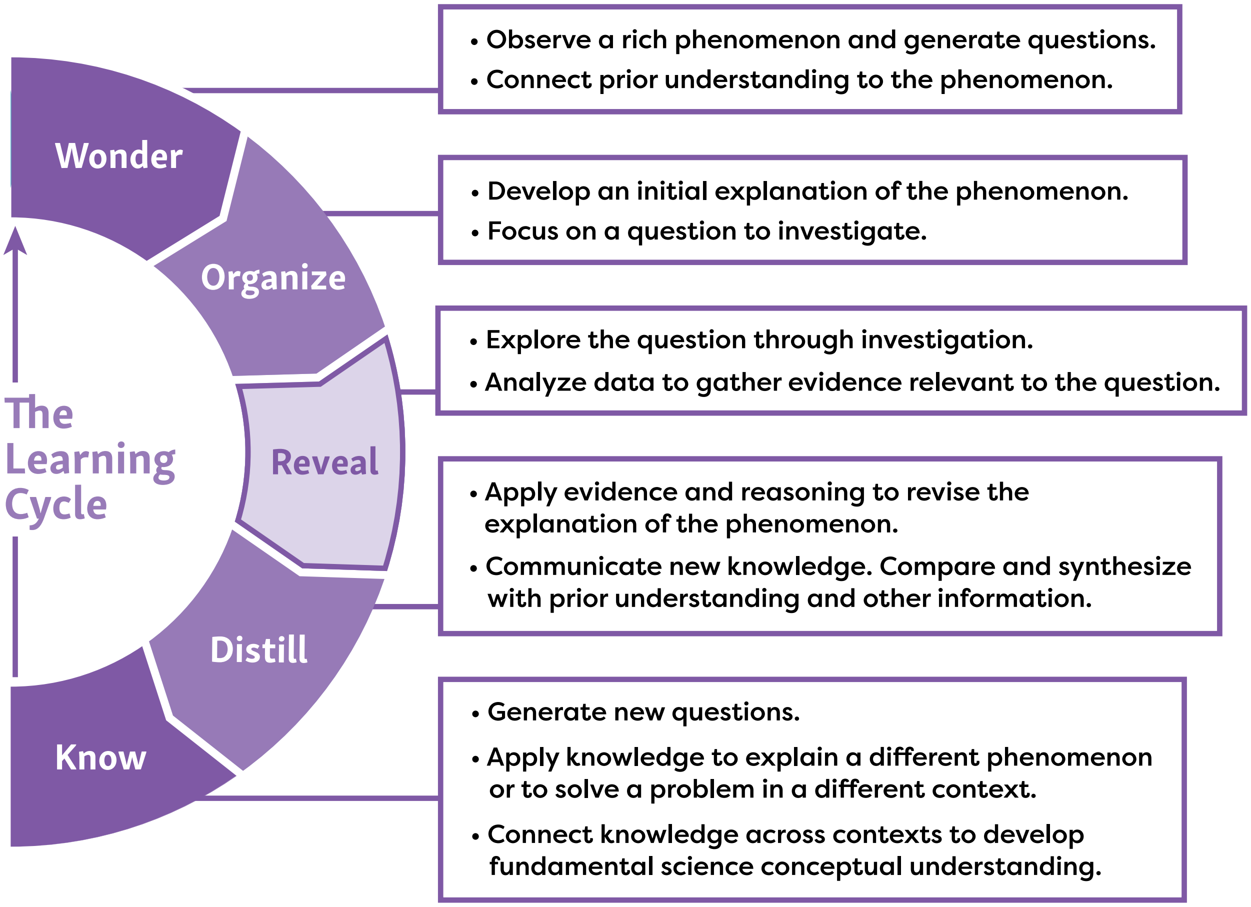
Throughout human history, natural phenomena have prompted questions and driven exploration. Bringing authentic phenomena into the classroom prepares students to question the world around them and gives them the tools necessary to apply their understanding to novel problems. Phenomenon-driven learning is a natural extension of students' innate way of approaching the world around them. As described in the *Framework*, "children entering kindergarten have surprisingly sophisticated ways of thinking about the world, based in part on their direct experiences with the physical environment" (NRC 2012, 24). An effective science curriculum helps students hone this natural inclination so that their mechanisms for explaining the phenomena around them continue to improve into adulthood. As a result, students grow to become "critical consumers of scientific information related to their everyday lives" (NRC 2012, 9).

Content Learning Cycle

THE *PHD SCIENCE* APPROACH TO THE LEARNING CYCLE

Throughout each module, students engage in the learning cycle to make sense of and explain the anchor phenomenon and supporting phenomena. Students begin each module by generating questions and developing an initial explanation of the anchor phenomenon. They then investigate various supporting phenomena to better understand the anchor phenomenon. Students periodically return to the anchor phenomenon to revise their explanation by applying evidence they gathered through their investigations and data analysis. At the end of the module, students reflect on the conceptual understanding they have developed and used to explain multiple phenomena in a Socratic Seminar and use that knowledge to explain a new phenomenon in the End-of-Module Assessment.

The learning cycle includes the five content stages shown in the following chart.



- Observe a rich phenomenon and generate questions.
- Connect prior understanding to the phenomenon.

- Develop an initial explanation of the phenomenon.
- Focus on a question to investigate.

- Explore the question through investigation.
- Analyze data to gather evidence relevant to the question.

- Apply evidence and reasoning to revise the explanation of the phenomenon.
- Communicate new knowledge. Compare and synthesize with prior understanding and other information.

- Generate new questions.
- Apply knowledge to explain a different phenomenon or to solve a problem in a different context.
- Connect knowledge across contexts to develop fundamental science conceptual understanding.

During each concept sequence in a module, students engage in one iteration of the learning cycle. Students usually Wonder, Organize, Reveal, and Distill multiple times within a concept sequence, but they may engage in the Know stage only once per concept. Depending on context, a learning cycle can be flexible to an extent. For example, students may engage in the Organize and Reveal stages several times before the Distill stage. However, they should always develop their thinking in the Wonder, Organize, and Reveal stages before synthesizing and applying that thinking in the Distill and Know stages. In the Distill stage, students develop a more complete explanation of a phenomenon based on evidence they gathered in the Reveal stage. For module-specific information on the application of content stages, see each module's Appendix B: Module Storyline.

Achieving the Standards

The shift to three-dimensional learning means that students develop scientific ideas while making sense of real-world phenomena or solving problems. Each time students participate in the learning cycle, they engage in elements of the DCIs by applying SEPs and the lens of CCs to make sense of phenomena.

The SEPs are particularly relevant to the content stages. Although all the practices may be applied in any stage, specific practices relate to each stage's focus. The *PhD Science* learning cycle incorporates the student actions described by the SEPs with the teacher actions described by the 7E (or 5E) instructional model.

The following table shows how particular SEPs and 7E phases relate to each stage of the *PhD Science* learning cycle.

Content Stage (Student Actions)	**Strongly Related SEPs** (Student Actions)	**Strongly Related 7E Phases*** (Teacher Actions)
Wonder	**SEP.1:** Asking Questions and Defining Problems	Elicit Engage
Organize	**SEP.2:** Developing and Using Models **SEP.6:** Constructing Explanations and Designing Solutions	Explore
Reveal	**SEP.3:** Planning and Carrying Out Investigations **SEP.4:** Analyzing and Interpreting Data **SEP.5:** Using Mathematics and Computational Thinking	Explore
Distill	**SEP.2:** Developing and Using Models **SEP.6:** Constructing Explanations and Designing Solutions **SEP.7:** Engaging in Argument from Evidence **SEP.8:** Obtaining, Evaluating, and Communicating Information	Explain
Know	**SEP.1:** Asking Questions and Defining Problems **SEP.6:** Constructing Explanations and Designing Solutions	Elaborate Extend
All		Evaluate

The Influence of the Learning Cycle

The learning cycle helps teachers and students understand important actions scientists take to develop explanations of natural phenomena and how those actions relate to one another. The *PhD Science* learning cycle is flexible and is not intended to prescribe a single scientific method or process. In scientific inquiry, scientists carefully observe the world, investigate areas of interest, and consider explanations for what they see. The *PhD Science* learning cycle helps students engage in scientific inquiry.

Students and teachers encounter related learning cycles made up of the same five content stages across content areas in the Great Minds curricula. The stages share names and overarching goals across content areas. However, the student actions the stages describe vary to reflect the goals and practices of each content area. These related learning cycles help students understand important differences between academic disciplines along with crosscutting patterns they can apply to learning in any context throughout their lives.

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* Although the Elicit and Engage phases both relate to the Wonder stage and the Elaborate and Extend phases both relate to the Know stage, each 7E phase includes unique elements that should not be conflated in instruction.

Safety

Great Minds believes that the safety and well-being of students are of utmost importance. In the science classroom, investigations frequently include demonstrations, experiments, engineering tasks, and other activities that involve unique safety concerns students do not encounter in other classroom settings. These investigations require careful planning and attention to safety protocols.

All educators, including teachers, administrators, and classroom aides, must be proactive in creating a safe science classroom. They must act responsibly and prudently to safeguard students, and they must serve as role models for safety at all times. With the cooperation of parents, educators can help ensure a safer classroom environment while providing students the opportunity to engage in high-quality science learning experiences.

At the outset of each school year, teachers should stress general science safety procedures and expectations with students. Teachers are encouraged to have students and parents sign a science safety contract that outlines the rules and procedures put in place to ensure a safe classroom experience. A safety quiz is also recommended to assess comprehension of these rules and procedures. Teachers may use the sample contract and quiz in each level's Module 1 Appendix A: Module Resources or create their own.

Teachers should revisit the safety rules and procedures frequently during the year. It is strongly recommended that teachers design and hang a safety poster in the classroom that students can refer to at any time, especially when teachers are explaining safety expectations before a science activity.

Teachers should exclude science investigation they believe cannot be performed safely due to inadequate safety engineering controls (e.g., fire extinguishers, ventilation systems, eyewash stations) or protective equipment (e.g., safety goggles, gloves, aprons). All adults present in the classroom are responsible for knowing the location of safety engineering controls, protective equipment, and first aid supplies and should receive appropriate training related to their use. If a particular safety measure is not available, teachers may elect to modify an investigation if doing so would reduce the safety risk while maintaining the integrity of the investigation.

For every science investigation, the teacher must thoroughly explain all relevant safety expectations, precautions, and procedures before students access materials or equipment. Teachers should monitor student actions and behaviors and immediately address concerns that arise. Students who disregard safety rules and procedures should be stopped from participating in the investigation until they have a better understanding of their actions and agree to abide by the safety rules and procedures. Unsafe behavior is not acceptable in a science classroom.

SAFETY IN THE ELEMENTARY CLASSROOM

High-quality science education requires that students participate in a wide variety of science investigations, including demonstrations, experiments, and engineering tasks. Kindergarten through Level 5 students can perform these activities in the classroom or other areas of the school, including a playground, field, or gymnasium when appropriate. Safety considerations appear in the Module Overview section of each module, and additional safety notes for teachers appear in lessons. These instructions should be regarded as the minimum safety precautions, and teachers may elect to implement additional safety precautions. Great Minds insists that teachers and students always follow the safety guidelines in this document.

Instructions

Students must follow printed safety instructions and oral safety instructions from adults in the classroom.

Behavior

Students must always practice safe classroom behavior. Running, pushing, yelling, or other inappropriate behavior is not acceptable during a science activity unless running or yelling is an integral part of the investigation. Inappropriate behavior can cause accidents. All supplies, equipment, and living organisms (such as plants and animals) must be handled carefully and respectfully.

Appropriate Dress

When conducting science investigations, students should tie back long hair, secure loose clothing, and wear closed-toe shoes.

Personal Protective Equipment (PPE)

- **Goggles:** Everyone in the classroom (including those who wear eye glasses) must use protective eyewear whenever science investigations involve
  - projectiles (anything flying through the air, either intentionally or unintentionally),
  - materials under stress or pressure (e.g., rubber bands, springs, wires),
  - glass (small shards of glass can become projectiles when glass breaks),
  - liquids (splashes of liquids, including water, can enter the eyes),
  - fumes (gases can enter the eyes),
  - sharp or pointed objects (e.g., bare wires, the edges of meter sticks), and
  - sand or powders (when disturbed, small particles, such as flour or fine sand, can be launched into the air and enter the eyes).

Goggles must be cleaned after each use. For more information on goggle use or cleaning protocol, consult the school's or district's guidelines and additional resources such as the American Chemical Society resource *Safety in the Elementary Science Classroom* (2011) (http://phdsci.link/1427) or the NSTA article "Eye Protection and Safer Practices FAQ" (2017) (http://phdsci.link/1428).

- **Gloves:** Nonallergenic gloves must be worn when working with chemicals, plants, or animals and at all times by students with open wounds on their hands.
- **Aprons:** Protective aprons must be worn when there is a danger of splatter or contamination of clothing.

Materials

- **Glass:** Objects used by students should be made of plastic, wood, or metal whenever possible. Glass breakage can produce extremely sharp surfaces, and glass shards may fly through the air. If glass breakage occurs, students must report the breakage to an adult; students must NOT attempt to clean it up. Teachers must inspect all glassware for damage before distributing it to students and after student use. Glassware must be washed after each use.
- **Thermometers:** A variety of thermometers are available for use in the classroom. Avoid using thermometers made of glass whenever possible. Thermometers containing mercury (silvery in appearance) must never be used in the classroom. Alcohol thermometers (containing red or blue liquid) are acceptable for classroom use.

- **Hot objects:** Students must not touch hot objects, such as incandescent light bulbs, hot glue guns, or hot plates. Water heated above 140°F should not be used by or near students in a classroom. Teachers handling hot objects must use appropriate tools, such as tongs.

- **Sharp objects:** Students must wear safety goggles and exercise great care when given permission to use sharp objects, such as scissors, other cutting tools, or wires.

- **Bright lights:** If an investigation involves light bulbs, students should be instructed not to stare at lit bulbs. Students must not handle lasers. If the teacher uses a laser for demonstration purposes, the teacher must never point it (or its reflection) toward students. Students must be instructed never to look directly at the Sun when activities or investigations involve observing the sky.

- **Organisms:** Students must not handle organisms, including plants, unless instructed to do so by the teacher. All organisms must be handled and treated with respect. Students must wash their hands immediately after handling organisms, including plants, and after handling soil, as it contains microorganisms.

- **Taste:** Students must never taste or place anything in their mouths during a science investigation.

- **Smell:** Students must never smell or inhale a substance unless instructed to do so by the teacher. If the teacher instructs students to smell or inhale a substance, instruction on proper technique (i.e., wafting) must also be given.

Food and Drink

- **Food:** Food must never be in the classroom during a science investigation. Outside food can contaminate or become contaminated by classroom materials.

- **Drink:** Beverages (including water bottles) must never be in the classroom during a science investigation. Outside beverages can contaminate or become contaminated by classroom materials. Additionally, spills on the floor can cause slips or falls, disrupt the investigation, or damage classroom materials.

Workspace

- **Cleanliness:** The classroom should be kept clean at all times, and students must clean up messes made during experiments. However, if glass breakage occurs, students must report the breakage to an adult, and students must NOT attempt to clean it up. After each hands-on science investigation, students must wash their hands with soap and water. Science materials and equipment, as well as desks and chairs, should be cleaned daily with disinfectants by school personnel.

- **Clutter:** The classroom should be kept as clear of clutter as possible. Objects on the floor (such as book bags) are a tripping hazard.

- **Electrical cords:** Extension cords should never be used in a classroom. Electric devices must be plugged in and unplugged by an adult, and the device must be securely placed so the cord is not a tripping hazard. Cords should never be on the floor, even if they are covered with tape or a rubber strip.

Internet Use

If students are permitted to conduct scientific research on the internet, their activity must be supervised to ensure that it conforms to school and district policies.

Additional Guidelines

In addition to these guidelines, teachers must follow their school's or district's health and safety guidelines. For additional information on science classroom safety, many resources are online and in print. Two such resources are the NSTA's "Safety Resources" web page (http://phdsci.link/1429) and the American Chemical Society's "Standards & Guidelines for Chemistry Education" web page (http://phdsci.link/1430).

Materials

PhD Science's development of investigations and materials lists involved considerable thought about ways to minimize costs. To help manage costs, schools and teachers must obtain some items used in the investigations locally. Most teacher- and school-supplied items can be found in the classroom or at local dollar stores, supermarkets, or hardware stores.

Materials lists in the Prepare section of each lesson set indicate the necessary quantity of each material. Materials in the Student section are per student unless otherwise noted. Materials in the Teacher section are per class unless otherwise noted. In addition to materials listed in the Prepare section, teachers should have access to the following common classroom items: sticky notes, chart paper, pencils, a whiteboard, and markers. K–2 teachers should also have access to sentence strips and a pocket chart.

Some module activities and investigations require advance preparation before a lesson. The Module Overview section of each module provides information about this required preparation. Lesson resources and the materials list in the Prepare section of each lesson offer additional details on materials preparation and instructions.

When materials have disposal requirements, protocols are provided in a resource. Great Minds supports smart environmental practices. Schools are encouraged to reuse, properly recycle (including wires and batteries), or compost materials when they can. For guidance on disposal of chemicals and other material wastes, consult the school's or district's laboratory waste management plan, the US Environmental Protection Agency (www.epa.gov), and the American Chemical Society (www.acs.org).

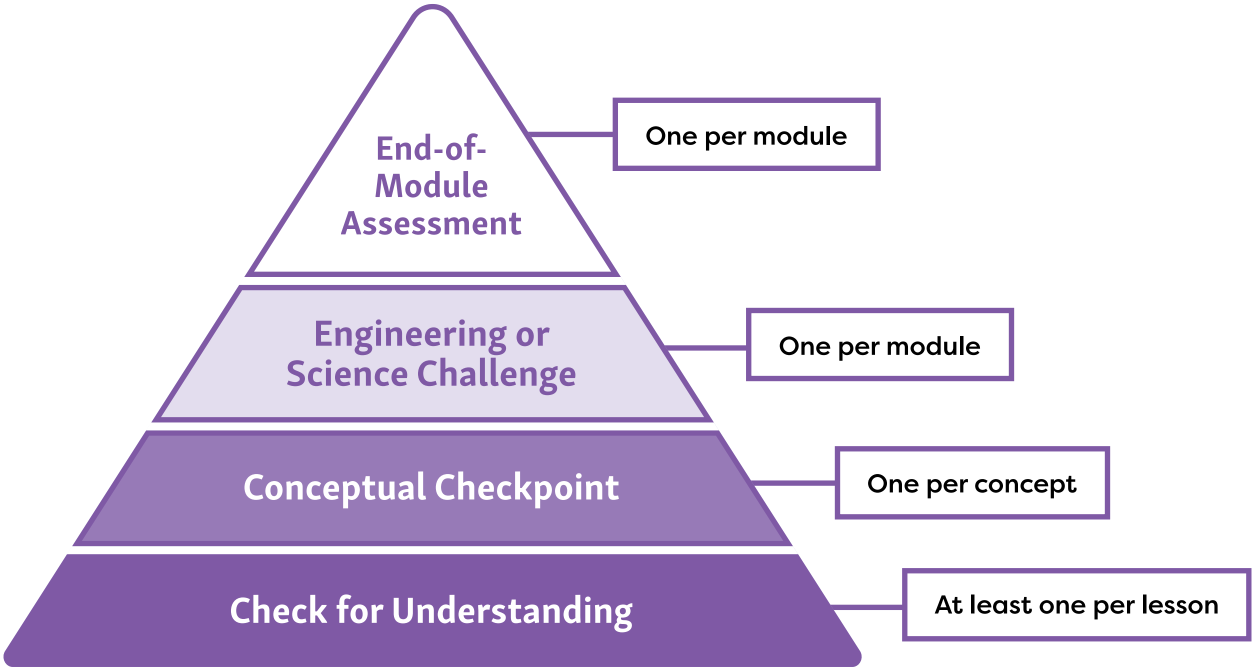
Going Deeper

Assessment

Assessing student progress toward mastery is key for student development and teacher planning. The *PhD Science* curriculum uses an authentic system of formal and informal assessments. Assessments engage students in three-dimensional, phenomenon-based tasks, helping teachers identify the scientific knowledge and skills students have gained. *PhD Science* also encourages the evaluation of other student work products for formative assessment purposes.

Throughout each module, four types of authentic assessment give students opportunities to make sense of phenomena by applying their knowledge and skills. Descriptions of the assessment opportunities appear below, with a summary in the figure.

- Checks for Understanding formatively assess students as they develop new knowledge and skills (at least one Check for Understanding per lesson for lessons that do not include another type of assessment; includes evaluation guidance).
- Conceptual Checkpoints assess mastery of knowledge and skills identified in each concept's standard(s) (one checkpoint per concept; includes evaluation guidance).
- Engineering Challenges and Science Challenges allow students to apply their conceptual knowledge to solve real-world problems through the process of engineering or investigation (one challenge per module; includes rubric).
- A summative End-of-Module Assessment gives students the opportunity to demonstrate the knowledge and skills they have acquired throughout the module in the context of one or more new phenomena (one assessment per module; includes rubric).



Students engage with assessment tasks in a variety of ways, and teachers may modify assessment items as needed while preserving scientific rigor. Some students may need additional processing time and supports as they complete assessments. To evaluate students' scientific understanding, teachers may find it necessary to read items to some students or allow students to answer orally with a scribe. Students may complete assessments individually or in groups; however, when using formative assessments summatively, teachers should evaluate individual student contributions rather than group performance.

Anchor Visuals

PhD Science uses recurring anchor visuals throughout each module to help develop coherence and to collect and display evidence of students' new knowledge, helping them integrate it with what they have already learned. Anchor visuals also make students' questions and thinking visible as they progress through each concept. As a class, students organize their learning in each module with a common set of three anchor visuals.

- **Driving question board:** a chart that drives learning from concept to concept by organizing phenomenon-based student questions and new questions that arise through investigation
- **Anchor model:** a model that students develop and modify throughout the module as new learning emerges to explain the anchor phenomenon
- **Anchor chart:** a chart containing key scientific understandings that grows as knowledge develops

The following table summarizes how teachers facilitate students' work with anchor visuals.

Driving Question Board

Overview	The **driving question board** is a tool to organize student questions about the anchor phenomenon; it can increase student engagement, highlight connections between concepts, and highlight the enduring knowledge pursued by students.
How It Works (Levels K–2)	1. After the anchor phenomenon is presented, students share questions about the anchor phenomenon or related phenomena. 2. The class posts unanswered questions in an Unanswered Questions area on the driving question board. 3. At the end of each concept, the class creates a new column to post answered questions related to the learning in that concept. Questions that are not associated with the learning in the concept or that are still unanswered remain in the Unanswered Questions area. 4. By the end of the module, many student questions are posted in a relevant column, while some are still unanswered.
How It Works (Levels 3–5)	1. After the anchor phenomenon is presented, students share questions about the anchor phenomenon or related phenomena. 2. Students organize their questions into categories that form the module concepts on the driving question board. 3. Students review the driving question board during each concept to discuss which questions they can answer and which are still open. At any time, they may also add new questions and learning to the board.

Anchor Model

Overview	The **anchor model** is a class model that students develop together throughout an entire module. By the end of a module, it should reflect students' explanation of the anchor phenomenon. Display the anchor model in the classroom so students can refer to and update it throughout the module.
How It Works (Levels K–2)	1. In Kindergarten, students work together to generate a class model that begins to explain the anchor phenonmenon. In Levels 1 and 2, students first develop individual models that they use to generate the class model. 2. This class model is recorded in a large format (e.g., on chart paper or as a physical model) with students' input. 3. The class develops the anchor model throughout the module and periodically updates it based on new evidence.
How It Works (Levels 3–5)	1. Students use individual models to generate a class model that begins to explain the anchor phenomenon. 2. This class model is recorded in a large format (e.g., on chart paper or a smart board) with students' input. 3. The class develops the anchor model throughout the module and periodically updates it based on new evidence.

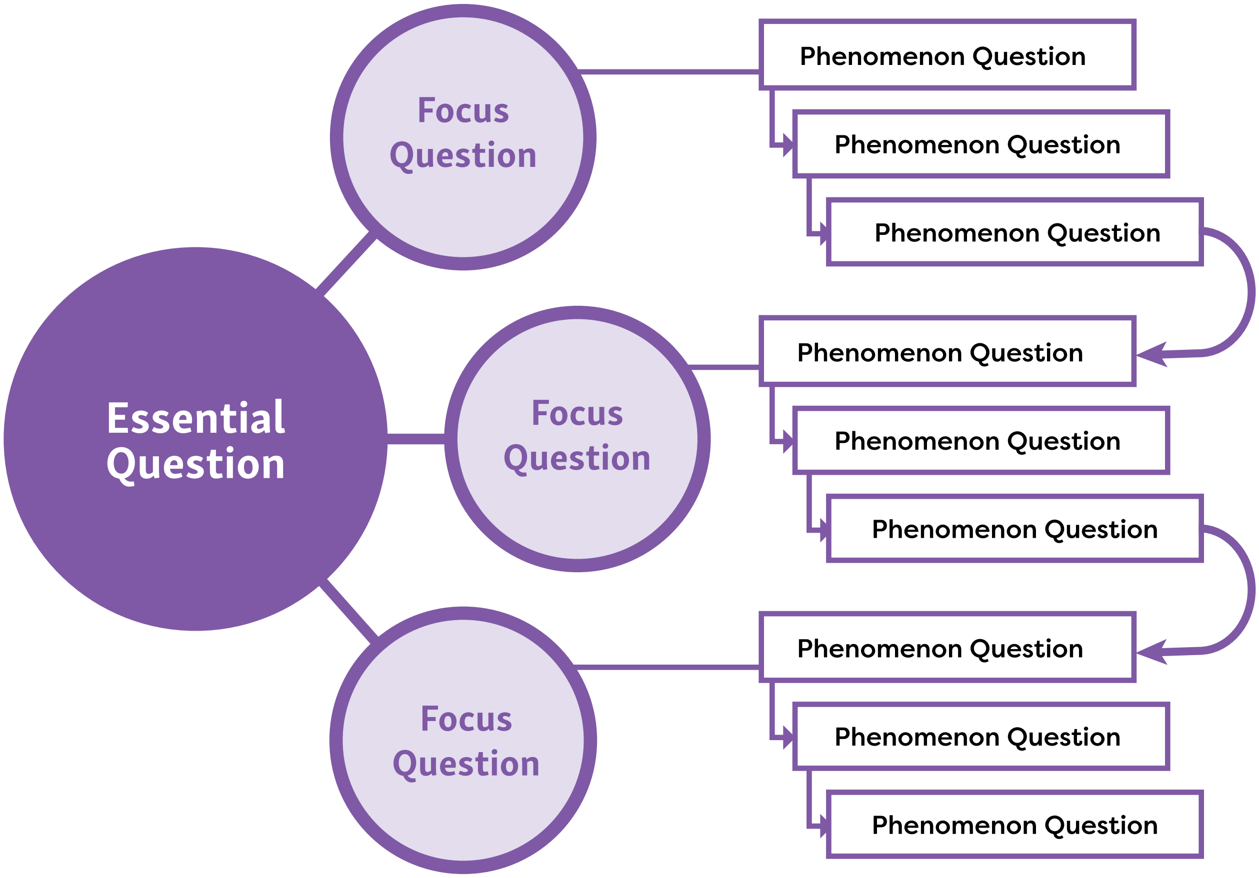
Anchor Chart

Overview	The **anchor chart** is a class summary of foundational learning that students develop together throughout an entire module. Display the anchor chart in the classroom so students can refer and add to it throughout the module.
How It Works (Levels K–2)	1. Write the title for the anchor chart on a sentence strip. 2. As students distill key science concepts from their learning throughout the module, use student input to record a summary of these concepts on sentence strips. Place the sentence strips in a pocket chart or affix them to a wall or whiteboard so that they are easy to move. 3. When applicable, place sentence strips from the anchor chart next to learning recorded on the anchor model and other class work products. Support students in making connections between key science concepts and their classroom learning. Always place sentence strips back on the anchor chart when done. 4. Refer to and encourage students to refer to the anchor chart during applicable lessons and activities.
How It Works (Levels 3–5)	1. Write the title for the anchor chart on a large sheet of chart paper. 2. Add information via student input as appropriate as students distill the key concepts from their learning. 3. Post, refer to, and encourage students to refer to the chart during applicable lessons and activities.

Questions

Throughout each module, three types of overarching questions play important roles in student learning. Lessons include suggestions on how teachers can facilitate discussions to help students develop these questions.

- The Essential Question inspires student learning throughout the module. Students formulate possible answers to this question through rich discussions and investigations, with the understanding that some scientific questions may never be fully answered. The Essential Question appears on the driving question board.
- Focus Questions anchor each concept sequence. By exploring each Focus Question, students build understanding related to the Essential Question. Focus Questions appear on the driving question board. In Kindergarten through Level 2, the class develops and adds a Focus Question at the end of each concept. In Levels 3 through 5, the class develops and adds all of the module's Focus Questions near the beginning of the module.
- Phenomenon Questions highlight the focus of students' exploration of a phenomenon, framing the purpose of each lesson set and connecting learning across lessons. Building knowledge by exploring one Phenomenon Question leads students to ask questions related to the next Phenomenon Question. Record Phenomenon Questions in a visible location so students can refer to them during lessons.



Discussions

Class discussions are an important component of the *PhD Science* curriculum. Scientific phenomena and investigations have been carefully selected to generate student questions and ideas and encourage student-driven learning. Class discussions provide students with opportunities to synthesize and communicate their understanding. Whenever possible, discussions should be student-driven and teacher-facilitated.

Lessons include sample teacher questions as well as sample student responses. These sample discussions demonstrate for teachers what a classroom discussion might sound like. They are an educative component—not a script—that illustrate a possible trajectory of questions and possible student responses. Because students generate questions and drive their own learning, questions and responses will vary from one classroom to another. Teachers should facilitate discussions that assess students' knowledge and skills, promote student-to-student discourse, and guide progress through a module. (See the Resources: Supporting Scientific Discourse section for more information.)

Because Great Minds believes that student discussions are crucial to active learning, teachers should consider giving students ample time to think and formulate answers or organize their thoughts by jotting them down before answering. Students can also share and discuss initial responses with a partner before sharing with the class.

Knowledge Deck Posters and Cards

The purpose of Knowledge Deck™ posters and cards is to engage K–2 students with accessible, knowledge-building texts that are worthy of study. Although K–2 *PhD Science* modules feature outstanding authentic texts whenever possible, texts that are accessible for these students do not yet exist for all module topics. For these topics, Great Minds offers high-quality, non-consumable, laminated Knowledge Deck posters, which feature visually arresting images and carefully crafted informational paragraphs that are polished, energetic, and punchy. Each Knowledge Deck poster is accompanied by a corresponding set of Knowledge Deck cards, which are smaller, consumable, and not laminated.

Knowledge Deck posters and cards are two-sided. They feature an image on the front and a different image and informational text on the back. Knowledge Deck image types include photographs, illustrations, fine art, historical primary and secondary sources, diagrams, and visual displays of data. The text on each poster consists of an informational paragraph, while cards have a shortened version of this information that is two to four sentences. Both posters and cards are written at a complexity level appropriate for teachers to read aloud to students. Knowledge Deck posters and cards are not intended for students to read independently.

English Language Development

While supporting language development is important for all students, it is especially important for English learners studying science. Students make meaning of language when they interact with new terms through coherent, hands-on experiences in the science classroom. For additional reading on language development in science, see *English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives* by the National Academies of Sciences, Engineering, and Medicine (https://doi.org/10.17226/25182).

PhD Science builds teachers' capacity to support English language development with a combination of generalizable best practices and lesson-specific examples of those practices in context. Lesson-specific supports are in every Teacher Edition in notes titled English Language Development. Some appear in the body of the lesson, while others appear in sidebars. Inline supports provide strategies beneficial to most students, such as explicit introduction to new terms and collaborative conversation routines, while sidebar supports provide targeted scaffolds for specific needs. Additionally, each module includes an appendix titled Domain-Specific Words, General Academic Words, and Spanish Cognates. Though this appendix is not comprehensive, it lists many important words and Spanish cognates, when available.

Teachers should use their expertise to apply best practices for English language development. The following sections describe transferable, research-based practices that teachers can customize to meet students' needs.

COLLABORATIVE CONVERSATIONS

Class discussions help students make meaning of science, but English learners may hesitate to participate. Creating opportunities for all students to speak and listen to their peers in varied contexts (in pairs, in small groups, and as a class) helps English learners build their conversational and academic language skills. For more details on routines for collaborative conversations, see the Resources: Instructional Routines section of this Implementation Guide.

GROUPING

Grouping students who speak the same native language at complementary proficiency levels can provide additional scaffolding by allowing English learners to converse in their native language, supporting English comprehension and understanding. For more details on grouping students, see the Supporting All Learners: Student Grouping section of this Implementation Guide.

EXPLICIT INTRODUCTION OF TERMINOLOGY

Explicitly introducing important terms creates a strong base for students to understand these terms. Terms should be introduced *after* students develop conceptual understanding in the context of exploring phenomena.

The process of explicitly introducing terms may include the steps below, which teachers can customize based on the word and students' needs.

- **Oral introduction:** The teacher pronounces the word aloud and students repeat it. This strategy provides direct practice in correct pronunciation and allows students to hear the word several times. Additionally, the teacher can break the word into syllables, and students can repeat the word in syllables before pronouncing the full word.
- **Morphology:** The teacher or students identify Greek or Latin roots, prefixes, and/or suffixes in the term and discuss the meaning of each part. For example, for the term *interact*, the teacher may say, "The word *interact* has two parts. The prefix *inter-* means 'together' or 'among,' and *act* means 'to do something.'" This practice helps students understand new terms while building skills for breaking down words into morphemes (the smallest part of a word that holds meaning). It helps to keep a running list of roots, prefixes, and suffixes in the classroom so students can refer to them and use them in future word analysis.
- **Cognates:** If possible, the teacher provides cognates (words sharing a common origin) for terms in students' native language. Examples of Spanish cognates include *prototipo* (*prototype*), *observación* (*observation*), and *descubrir* (*discover*).
- **Alternate definitions:** The teacher provides a student-friendly definition or explanation of the term. For example, for the word *dam*, the teacher may say, "A dam is a wall that blocks water from flowing." Associating *dam* with the familiar concept of a wall develops students' understanding by connecting the new word or concept to something they already know.

- **Varying contexts:** The teacher uses the word in more than one context. For example, a teacher introducing the word *layer* may say, “The word *layer* can be used in different ways. For instance, a cake can have layers. Each level of the cake is a layer. Or, if you feel cold, you may put on another layer of clothing, such as a coat or sweater.”

- **Images or movements:** While referring to words, providing relevant images is helpful. For example, when teaching the word *canyon*, the teacher may provide several pictures of canyons to help students associate the images with the word. Additionally, it may be helpful for students to connect movement with the meaning of an unfamiliar word. For example, when introducing the term *orbit*, the teacher may invite students to walk around their chairs. For more details on how to implement this strategy, refer to the Resources: Terminology Learning Routines section of this Implementation Guide.

SENTENCE FRAMES AND WORD BANKS

When asking English learners to use a new word in conversation or in writing, teachers may find it necessary to provide scaffolding beyond explicit introduction. Sentence frames and word banks can support students as they use terms in context and develop proficiency with the structure and syntax of English. The process of introducing new sentence frames and word banks may include the steps below, which teachers can customize based on the task, terminology, and students’ needs.

- **Frame:** The teacher reads the sentence frame aloud, and students repeat through choral reading. The frame should include the new target word so students fill in surrounding content and not the target word itself. The frame provides a scaffold for students’ use of new terms and allows for varied responses.

- **Sample sentence:** The teacher uses the frame and reads a sample sentence, which the students repeat.

- **Independent application:** Students use the frame to write or say their own sentences. Students might confer with a partner before completing the sentence.

- **Partner sharing:** Students share their sentences aloud with a partner. Sharing with a partner allows all students to practice using the term orally. Creating opportunities for all students to share their ideas orally enables practice and reinforcement of academic vocabulary and syntax.

- **Class sharing:** Instead of asking for volunteers or calling on students randomly, the teacher selects several students to share sentences with the class, eventually hearing from all students throughout several days or a week. Giving students a question to answer in advance allows them to prepare their answers and respond confidently.

Customizing sentence frames with word banks can offer more support or a greater challenge. A word bank might include basic terms for English learners or challenging terms for students working above grade level. For example, the frame for a sentence containing the target term *observed* might be “We took our pet to the veterinarian after we observed that he was _____.” The word bank might include words and phrases such as *acting strangely* or *sleeping more than usual* for English learners and *feverish* or *lethargic* for students working above grade level.

Teachers may create reusable sentence frames for tasks and concepts the class encounters frequently. For example, many *PhD Science* lessons ask students what they notice and wonder about an image or a text. Students may use sentence frames such as “I notice _____” and “I (think/wonder) _____ because I see _____.” Students can use these sentence frames every time they complete a notice and wonder task, gradually increasing their independence as they become more proficient with the language.

Spanish Translation Considerations for *PhD Science*

OVERVIEW

PhD Science takes a unique approach to phenomenon-driven instruction by embedding scientific phenomena in a cultural context. As students explore a phenomenon, they study carefully curated core and other module texts, artwork, and primary sources that tell relevant historical and cultural stories. Some resources are available only in English. The translation team suggests alternatives to those resources to ensure a comprehensive learning experience for Spanish-speaking students in a variety of classroom environments.

SPANISH TRANSLATION APPROACH

To determine how best to translate a *PhD Science* module, the translation team begins with an in-depth analysis of the corresponding English module. The team identifies curriculum components, such as lesson notes and external links, that require adjustment for Spanish-speaking students to better understand relevant science concepts.

TRANSLATION OF CORE TEXTS AND OTHER MODULE TEXTS

Wherever possible, the Spanish curriculum integrates Spanish-language texts. The curriculum uses translations of all available core and other module texts. If a text does not have an official Spanish translation, the curriculum may take a blended approach, pairing a Spanish-language text with images from an English-language text. Spanish PhD Projected slides—module-specific, annotated student-facing slides that supplement the Teacher Edition—support teachers by identifying module texts that require a blended approach. When using PhD Projected slides, teachers should consider keeping the notes section open to view additional guidance on how to present module texts.

TRANSLATION OF EXTERNAL RESOURCES

Some student-facing activities require external resources, such as videos and web pages, that offer the automatic translation options the following sections detail. If a resource does not offer automatic translation, the Spanish curriculum provides a Spanish-language summary, a link to a Spanish translation, or a link to an accessible video with Spanish closed captions. When using PhD Projected slides, teachers should consider keeping the notes section open to access any provided video summaries.

Automatic Translation of Web Pages

A web browser's automatic translation feature translates the text on a web page from one language to another. Text translated with the automatic translation feature does not always meet the high quality standard that Great Minds translated materials aim to. However, it is a useful tool that can make English-language content accessible to Spanish-speaking students. The instructions to turn on the automatic translation feature are unique to each browser. To find instructions for a specific browser, teachers can search for a key phrase such as "how to automatically translate a web page." Teachers should follow the instructions to translate English text to Spanish.

Automatic Translation of Closed Captions in Videos

A video player's automatic translation feature translates video closed captions from one language to another. The instructions to turn on this feature may vary, and the feature may not be available for all videos. To find instructions, teachers can search for a key phrase such as "how to watch videos with auto-translated captions." Teachers should follow the instructions to change English closed captions to Spanish closed captions.

SPANISH SUPPORT RESOURCES

The Spanish curriculum offers a list of Spanish-language module texts and external resources by level. Teachers can access this list from the home page of the Teacher Resource Pack, a collection of free instructional materials and tools.

TRANSLATION OF INSTRUCTIONAL LANGUAGE

When translating a module, the translation team follows the latest guidance from Real Academia Española (http://www.rae.es), an institution that regulates the Spanish language as it evolves. In particular, the team consults the dictionary *Diccionario panhispánico de dudas* (https://www.rae.es/dpd/) and the Fundéu website (http://www.fundeu.es). These resources provide teachers and students opportunities to learn new science terms and other words in Spanish as well as current Spanish language norms.

Terminology

Science terms: As students build knowledge of science concepts throughout a module, the *PhD Science* curriculum introduces science terms and supports students in applying those terms correctly. During the translation process, the translation team looks especially closely at common names of species. The team identifies the Latin name of each species and consults multiple scientific resources to determine the most accurate Spanish translation. The team uses the following resources, among others, to translate names of species:

- The encyclopedia Enciclovida (https://enciclovida.mx)
- The databases iNaturalist Mexico Project (https://www.inaturalist.org/projects/mexico), iNaturalist Colombia (https://colombia.inaturalist.org), and iNaturalist Ecuador (https://ecuador.inaturalist.org)

English words: The Spanish curriculum aims to situate science learning in contexts that relate to students' daily lives. Spanish-speaking students in the United States are surrounded by English-language signs, labels, and other printed materials. For this reason, the curriculum retains English words that do not have a Spanish equivalent, such as *pretzel* and *hockey*, and formats them in italics.

STYLE CONSIDERATIONS

Accent marks: Per Real Academia Española's latest recommendations on punctuation, the Spanish curriculum does not use accent marks in the following cases:

- In demonstrative pronouns, except to prevent ambiguity between an adjective and a pronoun
- In the word *solo*, except to prevent ambiguity between an adjective and an adverb
- When the letter *o* appears between numbers

Numbers: Because students who use the Spanish curriculum live in the United States, the way Spanish punctuates numbers could confuse students. For this reason, the Spanish curriculum uses American punctuation. The curriculum places a comma after every third digit from the right (e.g., *1,000*) and uses a period as a decimal marker (e.g., *4.25 miles*).

Titles of articles and text excerpts: If no official Spanish translation of an article or excerpt exists, the Spanish curriculum uses the English title and provides a parenthetical courtesy translation the first time the title appears.

Trademarked materials: Trademarked products and materials that do not belong to Great Minds and for which no official Spanish translation exists remain in English. The Spanish curriculum provides a parenthetical courtesy translation the first time such a product or material appears.

Daily videos: Viewers may notice that in both English and Spanish book titles in video closed captions appear in quotation marks rather than italics. Technology requirements necessitate this convention.

PROGRAM CONSIDERATIONS

Whether teachers work in a transitional bilingual education program (early-exit or late-exit) or in a dual-language immersion program (one-way or two-way), they should help students understand the enrichment opportunities a bilingual environment can offer. During instruction, teachers should emphasize the value of students knowing science terms in both English and Spanish and should try to make cross-linguistic connections. Teachers may also use word walls, content walls, word sorts, and other activities that highlight cognates between English and Spanish. At the same time, teachers should explain the nuances of English words that do not have a Spanish equivalent.

Supporting All Learners

Great Minds believes that all students can engage meaningfully with science. To this end, the curriculum provides all students access to learning science through the three-dimensional approach of the NGSS with specific supports based on the research-based Universal Design for Learning (UDL) Guidelines from the Center for Applied Special Technology (2018)[†]. The priority of *PhD Science* is to appropriately challenge all learners by providing scaffolds for achieving grade-level standards and opportunities to exceed these standards in developmentally appropriate ways. *PhD Science* is distinctive because it integrates supports throughout the curriculum. Rather than providing alternate learning activities, *PhD Science* integrates supports in each lesson.

UNIVERSAL DESIGN FOR LEARNING FRAMEWORK

PhD Science makes science learning accessible to all students by incorporating the three guiding principles of the UDL framework. All *PhD Science* instructional sequences provide multiple means of

- student **engagement** to motivate learning,
- **representation** in presenting information to students, and
- student **action and expression** to demonstrate what they know and can do.

The principles of UDL make it possible for all students to achieve success in all three dimensions of the NGSS and give students ownership of associated knowledge and skills. The following sections describe many ways in which *PhD Science* integrates these principles in lessons.

Provide Multiple Means of Engagement

Engaging students in learning begins with compelling phenomena that interest them. *PhD Science* features multifaceted phenomena that spark student curiosity about many aspects of one phenomenon. Students generate their own questions, work together to make sense of phenomena, and gather evidence to build scientific knowledge.

PhD Science lessons engage students on many levels and in a variety of ways:

- They help students see how science is relevant to students' lives.
- They foster collaborative sense-making through such tasks as the development of anchor visuals.

[†] Culturally responsive pedagogy in *PhD Science* also makes learning accessible to all students, including students of diverse economic backgrounds, racial and ethnic groups, gender identities, and education programs. For more information, see Culturally Responsive Pedagogy.

- They provide opportunities for productive discussion and interactions with others.
- They provide opportunities for active participation, exploration, and investigation.
- They encourage students to solve problems creatively, which allows them to make sense of complex phenomena in different ways.
- They provide opportunities for personal response, evaluation, and self-reflection.
- Creating cooperative learning groups with clear expectations for group work

Provide Multiple Means of Representation

Students must engage with different types of information to make sense of phenomena. Narrative, explanatory, and quantitative information can all describe important aspects of phenomena and science ideas. Information can be represented through images, written and spoken words, symbols, videos, hands-on experiences, and many other means. Interaction with multiple representations allows all students to access complex phenomena.

PhD Science lessons promote multiple means of representation in a variety of ways:

- Using models, images, graphics, animations, videos, and audio recordings as alternatives or additions to textual information
- Using interactive models
- Providing graphic organizers, templates, and concept maps
- Providing auditory or written descriptions for images, graphics, videos, and animations
- Allowing students to develop and communicate ideas while making sense of a phenomenon before presenting relevant science terms
- Incorporating strategies to help students apply skills from other content areas, including English and mathematics, in a scientific context when necessary for them to make sense of phenomena
- Connecting learning to students' prior knowledge
- Providing scaffolds for learning in all three dimensions of the NGSS

Provide Multiple Means of Action and Expression

Like scientists, students must use multiple modalities to express their understanding and rely on discourse to develop knowledge. Students take part in purposeful discussions in which they clarify, justify, and interpret their own ideas and respond to others' ideas to build understanding.

PhD Science lessons promote multiple means of action and expression in a variety of ways:

- Providing many different means for expression, such as writing, speaking, drawing, modeling with a variety of materials, annotating, gesturing, pointing out, video recording, and creating tables and charts
- Integrating collaborative conversation routines and techniques (see Resources: Instructional Routines section for more information), such as Think–Pair–Share and Question Corners
- Integrating written response routines (see Resources: Instructional Routines section for more information), such as Chalk Talk and Gallery Walk

DIFFERENTIATION SUPPORTS

While lessons include versatile learning activities designed for all students, they also include in-the-moment Differentiation supports that provide examples of how teachers may customize instruction to support specific learning needs. Many students may benefit from the Differentiation supports; however, the supports focus on learners with physical and cognitive challenges, learners performing above or below grade level, and English learners. *PhD Science* encourages teachers to use their professional knowledge of best practices and students' needs to provide additional supports that respond to each student's unique needs.

The following sections describe several instructional practices relevant to implementing *PhD Science* lessons in ways that support all students.

Student Grouping

Grouping students strategically promotes multiple means of student engagement, action, and expression. There are many ways to group students, and every teacher knows what works best for their class and students. When grouping students, consider the task they are to complete.

Grouping students with diverse abilities works well when students perform an open-ended task and each student has a specific role in the task (e.g., reading, recording data, note-taking). This student grouping method allows all students to participate and collaborate to complete a task, brings together students with complementary skills, and encourages a positive classroom culture.

Grouping students with similar abilities or interests works well in tasks where different students read portions of the same text or apply mathematical skills to solve complex problems. This student grouping method allows students to collaboratively follow common interests or apply shared skills.

Reading Complex Texts

Supports for reading complex texts promote multiple means of representation. Many science texts are both qualitatively and quantitatively complex. Various strategies can help students use complex texts more effectively. Some examples are using digital tools, participating in teacher-facilitated reading groups, and reading complex texts multiple times. Digital tools may help teachers who want to increase student participation in text-based activities and discussions. Several text-to-speech reading applications, such as Read&Write for Google Chrome™, are available to install on digital devices. These reading supports enable striving readers to participate in text-based activities more efficiently. Teacher-facilitated reading groups, in which a teacher reads to students, help the teacher check for student comprehension throughout the reading. Reading a complex text multiple times and focusing on a distinct purpose for each read helps students become more comfortable with the text.

Videos and Images

Supports for accessing videos and images promote multiple means of representation. Videos and images are useful for increasing comprehension of concepts that may be difficult to grasp through words alone. Providing transcripts of videos may help some students, particularly students with auditory impairments, make deeper connections with the concepts the videos present. Teachers can also highlight transcripts to help students access important information. Offer a transcript after students view the video once so that they can focus on the video without the distraction of trying to read along.

Students with visual impairments may have limited ability to interact with videos and images. Consider providing preferential seating, enlarged images and videos, printed copies of projected images, auditory descriptions of images, or written descriptions of images to students.

Models and Investigations

Supports for modeling and investigating promote multiple means of action and expression. Students develop and use models and carry out investigations in each module of *PhD Science*. Students learn best when completing most of the model development or investigation activities themselves. However, students may benefit from precut, partially predrawn, or preassembled components when developing some models.

Certain materials that students interact with may require modifications for students with tactile sensitivities. Materials such as sand, gravel, soil, and construction paper may limit some students' participation. Providing rubber gloves may help some students, while others may require assignment of a group role that does not involve handling the materials. Examples of such roles are taking pictures, video recording the group's discussions and work, or documenting information. Ensure that all students have an active role during the modeling process or investigation.

Culturally Responsive Pedagogy

Great Minds believes that science matters for all students and that all learners possess a rich background of cultural knowledge, experiences, and interests that can be authentically integrated in their science learning. *PhD Science* lessons use students' diverse cultural and social backgrounds to support all students in engaging with science and understanding why it matters to them. Culturally responsive pedagogy creates equitable learning experiences for all students, including learners of diverse economic backgrounds, racial and ethnic groups, gender identities, and education programs.

PhD Science supports culturally responsive and sustaining pedagogy through various aspects of its curriculum design, including

- **equitable access** for all students to meet **rigorous expectations**,
- students' **active engagement** in the process of developing knowledge,
- **student-centered learning** whereby students understand how their questions and ideas contribute to the process of learning,
- **specialized language development** as a product of conceptual understanding, and
- acknowledging and valuing diverse contributions to the science community through **cultural pluralism**.

A description of each aspect appears in detail below with related research, the ways *PhD Science* helps teachers put research-supported best practices into action, and examples of these practices from modules in Levels K–5. Additionally, Great Minds understands that each classroom is unique and encourages teachers to use their professional knowledge and relationships with students to make in-the-moment decisions about practicing culturally responsive pedagogy. Accompanying implementation recommendations support these decisions.

RIGOROUS EXPECTATIONS AND EQUITABLE ACCESS

Research Says	*PhD Science* Responds
Teachers convey confidence by "exposing students to an intellectually rigorous curriculum, teaching students strategies they can use to monitor their own learning, setting high performance expectations for students and consistently holding them accountable for meeting those expectations, encouraging students to excel, and building on the individual and cultural resources they bring to school. Strategies such as these, which convey respect for students and affirm their differences, become the basis for meaningful relationships between teachers and students and produce favorable academic results (Gay 2000; Irvine 1990; Ladson-Billings 1994; Lucas et al. 1990)" (Villegas and Lucas 2002, 23). "All individuals, with a small number of notable exceptions, can engage in and learn complex subject matter—especially if it connects to areas of personal interest and consequence—when supportive conditions and feedback mechanisms are in place and the learner makes a sustained effort" (NRC 2012, 280). "When we hold the expectation that understanding is a chief goal of learning and take students further and demand more of them than solely focusing on the acquisition of knowledge and skills, then our teaching becomes focused on deep rather than surface learning. An expectation for student independence rather than dependence demands a different way of teaching as well, one that empowers rather than controls students" (Ritchhart 2015, 7). "Successful application of science and engineering practices … and understanding of how crosscutting concepts … play out across a range of disciplinary core ideas … will demand increased cognitive expectations of all students. Making such connections has typically been expected only of 'advanced,' 'gifted,' or 'honors' students. The NGSS are intended to provide a foundation for all students, including those who can and should surpass the NGSS performance expectations. At the same time, the NGSS make it clear that these increased expectations apply to those students who have traditionally struggled to demonstrate mastery even in the previous generation of less cognitively demanding standards" (NGSS Lead States 2013, 359).	Great Minds believes that all students are capable of meeting the rigorous expectations set forth in the NGSS. To achieve this goal, the curriculum presents the same expectations for all students and provides teachers with support strategies that ensure students have equitable access to a phenomenon and the science information they need to make sense of that phenomenon. Curiosity motivates learning as students work to make sense of compelling, complex, and knowledge-rich phenomena. Teachers can harness this intrinsic motivation to help all students meet the same rigorous expectations. *PhD Science* lessons present phenomena through multiple modalities—including videos, photographs, authentic texts, art, music, and firsthand experiences. As students make sense of phenomena, they build conceptual understanding through hands-on experience. Hands-on investigations provide all students with shared opportunities to collect evidence, develop and evaluate their ideas, and build scientific explanations. (See Going Deeper: Supporting All Learners for more information on how *PhD Science* helps all students meet rigorous expectations.) Additionally, formative and flexible assessments provide opportunities to check student progress toward expectations. Check for Understanding and Conceptual Checkpoint boxes provide examples of evidence teachers should look for to gauge student learning as well as next steps to support all students in reaching proficiency. Summative End-of-Module Assessments allow students to apply what they have learned to a new phenomenon or context, with their unique classroom experiences providing the background knowledge necessary to complete the assessment.

Examples in *PhD Science*

- End-of-Module Assessments and Conceptual Checkpoints require students to use the conceptual knowledge they build throughout the module to make sense of a new phenomenon or a similar phenomenon in a new context.
    - In a Level 1 Module 3 Conceptual Checkpoint, students apply their understanding of how sound affects nearby objects to make a prediction about whether sound from a low-flying airplane will affect nearby houses by causing them to vibrate.
    - In a Level 3 Module 4 Conceptual Checkpoint, students watch and record the pattern of motion of a slingshot capsule at an amusement park. They predict the height of the capsule at 20 seconds and support their prediction with evidence from classroom investigations.
    - In the Level 4 Module 1 End-of-Module Assessment, students apply what they have learned about Earth's features by selecting the best explanation for how landforms have changed over time in an unexplored canyon. Students support their choice with evidence from the assessment materials.
- Most modules include an Engineering Challenge, in which students develop a solution to a real-world problem. Students engage in the engineering design process while considering the criteria for success and the limitations imposed by constraints. Engineering Challenges hold all students to the same expectations while promoting student creativity and choice.
    - In Level K Module 4, students use their understanding of the impact of trash on the environment to solve a real-world problem. Students create biodegradable paper planting pots by testing different kinds of paper to determine which kinds best contain soil and water like plastic does.
    - In Level 2 Module 3, students use their knowledge of how pollinators transfer pollen from one plant to another to solve a problem. Students develop pollination tools that can help humans pollinate plants in the absence of pollinators.
    - In Level 5 Module 3, students create a sustainable farming system that conserves fresh water by applying their knowledge of the ways in which Balinese rice farmers harness the interactions of Earth's systems.

Implementation Recommendations

- Develop a classroom environment that respects all students' capabilities by encouraging students to meet expectations, acknowledging their efforts, and offering evidence-based feedback when expectations are met.
- Hold all students accountable for their learning while allowing them to demonstrate their knowledge in various ways. For example, allow students to choose how they present their learning (e.g., writing, drawing, speaking).
- Provide scaffolded opportunities for students to communicate in a variety of ways.
- Provide students with additional access points to anchor phenomena related to student backgrounds, experiences, and interests, such as
    - additional images and videos of the phenomenon,
    - firsthand accounts of the phenomenon, and
    - observations of related local phenomena.

When selecting additional resources, consider whether a resource divulges key information about a phenomenon before students build this knowledge independently.

ACTIVE ENGAGEMENT

Research Says	***PhD Science* Responds**
"The framework reflects the fact that students learn science in large part through their active involvement in the practices of science. A classroom environment that provides opportunities for students to participate in scientific and engineering practices engages them in tasks that require social interaction, the use of scientific discourse (that leverages community discourse when possible), and the application of scientific representations and tools. Science and engineering practices can actually serve as productive entry points for students from diverse communities—including students from different social and linguistic traditions, particularly second-language learners" (NRC 2012, 283). "A culturally mediated way of thinking and knowing suggests that learning can be defined as engagement with scientific practices" (Brickhouse, Lowery, and Schultz 2000, 441).	With *PhD Science,* students engage in a content learning cycle of asking questions and sharing initial ideas about a phenomenon, investigating those questions, developing evidence-based explanations, and finally transferring their new knowledge to explain related phenomena. As students arrive at DCIs by applying SEPs through the lens of CCs, they move from *reading about* science to *doing* science. (See Getting Started: Content Learning Cycle for more information on how *PhD Science* engages students in building understanding.) SEPs play an essential role in all modules by promoting active engagement and encouraging students to work as scientists. An important way that students engage with these practices is through scientific discourse. During each step of the learning process, students communicate their new and developing understanding by using modalities such as home or everyday language, gestures, symbols, and the written or spoken word. Scientific discourse in *PhD Science* removes barriers for students who may not be able to express their learning through traditional writing assignments. Similarly, the communication of ideas through models and sketches increases opportunities for student engagement.

Examples in *PhD Science*

- Planning and carrying out investigations allows students to gather personally meaningful evidence to support their scientific explanations.
    - In Level K Module 3, students plan an investigation to test the effects of water and light on bean plants. Students make and record observations and then analyze their data to develop an evidence-based claim about the needs of bean plants.
    - In Level 3 Module 4, students plan and carry out investigations to find out what causes objects to slow down and stop as they move across different materials.
    - In Level 4 Module 2, students design an investigation to manipulate the energy input of a system and observe the cause and effect relationship between energy and speed.
- Students use mathematics and computational thinking to analyze data and determine whether the data support their claims.
    - In Level 2 Module 3, students graph and analyze data from a module-long plant investigation to determine that different kinds of plants require different amounts of resources to best meet their needs for growth.
    - In Level 4 Module 4, students build and test solutions to increase the visibility of Howland Island. Students collect and analyze data they can use to evaluate and improve their designs. They present their improved designs to peers and create a line plot to compare multiple solutions. They then use the data as evidence to support a claim about which design best meets the criteria and constraints.
- Students use models to understand, explain, and collect evidence about phenomena. In each module, students make sense of the anchor phenomenon through the incremental development of an anchor model. To update the anchor model, students must distill information and evidence they have gained from classroom experiences. In this way, the anchor model is the culmination of student engagement in the SEPs.
    - In Level 1 Module 1, students use models of plant and animal body parts to describe ways pond plants and pond animals survive in their environment. These models help students understand that plant and animal body parts have many different functions and that these functions help plants and animals survive.
    - In Level 3 Module 4, students develop models to explain how different forces acting on an object affect its motion on Earth and aboard the International Space Station.
    - In Level 5 Module 4, students develop and refine models of the interactions of Earth, the Sun, the Moon, and stars from the perspectives of Earth and space. By refining these models over time, students develop an understanding that the movements of Earth and the Moon in space explain their observations.

Implementation Recommendations

- Support students’ appraisal of their own understanding by allowing them to talk openly about their explanations, claims, evidence, and reasoning. Support evidence-based discourse by using Collaborative Conversation Prompts. (See Resources: Supporting Scientific Discourse for further guidance.)
- Involve students in identifying the stage of the learning cycle they are experiencing to increase metacognitive awareness of scientific inquiry. (See Getting Started: Content Learning Cycle for more information on the stages of the Learning Cycle in *PhD Science*.)

STUDENT-CENTERED LEARNING

Research Says	*PhD Science* Responds
"Student-centered instruction differs from the traditional teacher-centered instruction. Learning is cooperative, collaborative, and community-oriented. Students are encouraged to direct their own learning and to work with other students on research projects and assignments that are both culturally and socially relevant to them. Students become self-confident, self-directed, and proactive. Children develop cognitively by interacting with both adults and more knowledgeable peers. These interactions allow students to hypothesize, experiment with new ideas, and receive feedback" (Darling-Hammond 1997). "For students, posing their own questions is a first step towards filling their knowledge gaps and resolving puzzlement. The process of asking questions allows them to articulate their current understanding of a topic, to make connections with other ideas, and also to become aware of what they do or do not know" (Chin and Osborne 2008, 2).	Throughout each *PhD Science* module, student questions about compelling, relevant, and authentic phenomena are the catalyst for learning. Students make their questions about phenomena visible by using tools such as the driving question board and notice and wonder charts. Teachers facilitate discussions about these questions, synthesizing student ideas to develop the Essential Question, Focus Questions, and Phenomenon Questions that frame student inquiry. Through these experiences, students gain ownership of their learning rather than passively following teacher-directed goals. Through carefully designed lesson activities, students learn in a collaborative, cooperative, and community-oriented environment. During collaborative conversations, students learn from peers and voice ideas based on their prior knowledge and cultural backgrounds as well as evidence they gathered in class. They frequently engage in cooperative tasks such as investigations and Engineering Challenges. Classes collaboratively represent questions and ideas with anchor visuals such as the driving question board, anchor model, and anchor chart. In each lesson, students work together to develop, use, and express knowledge.

Examples in *PhD Science*

- At the beginning of each module, students ask questions about the anchor phenomenon and develop a driving question board. Students continue to interact with the driving question board throughout the module as they add new questions and consider which questions they can answer and which still need to be addressed.
  - In Level K Module 2, students use observations of the anchor model, a Knowledge Deck poster, and a text to develop a driving question board about tugboats in a harbor. Students revisit the driving question board throughout the module to review questions and ask new questions.
  - In Level 2 Module 2, students observe photographs of the transformation of the island of Surtsey and wonder what might cause an island to change shape over time. They use their observations and questions to develop a driving question board. Students continue to explore their questions throughout the module to learn that natural events transform Earth's land as time passes.
  - In Level 3 Module 3, students develop a driving question board based on their observations of multiple humpback whales and their questions about what makes an individual humpback whale unique. Students revisit the driving question board periodically to add new questions, assess their progress toward answering the Essential Question, and review questions they can answer from the evidence they have gathered.
  - In Level 5 Module 1, students use the driving question board to share questions they have about how the Statue of Liberty has changed color over time. Students group their questions into categories and work with the teacher to develop a Focus Question for each category. Students revisit the driving question board at the end of Concept 1 to see what questions they can answer and to add new questions that have arisen related to Concept 2 and Concept 3 in light of their new understandings of particle motion in gases.
- A Socratic Seminar in each module engages students in a deeper examination of the Essential Question, allowing them to synthesize and extend their learning through peer-to-peer discussion and debate. These conversations go beyond summarizing learning.
- Instructional routines provide opportunities for students to collaboratively build content knowledge, deepen understanding, and develop critical thinking skills. Instructional routines increase student engagement and make students' thinking and learning visible. Notes in the Teacher Edition introduce new instructional routines and establish guidelines for students.
  - The Tableau routine encourages students to visually and kinesthetically express understanding of a concept. In a Level K Module 3 extension activity, students work in groups to pose in ways that show how plants responded to specific water and light conditions during an investigation. After each group performs, other students discuss how the group represented the plant data.
  - The Jigsaw routine allows students to work and learn collaboratively. In Level 3 Module 2, groups of students read about different animal species that live together. Each group then shares its new knowledge with the class. Through this discussion, students gather information that allows them to compare different animals and make claims about why these animals live in groups.
  - The Chalk Talk routine fosters universal participation and helps students organize their thinking. Students participate in a silent conversation by writing thoughts and questions about a topic on the board or on sheets of chart paper. As they consider each topic, students are encouraged to build on their peers' ideas, respond to questions, and write follow-up questions. Level 3 Module 1 uses this instructional routine to explore different solutions people use to mitigate severe weather damage.

  - A Gallery Walk allows students to view and provide feedback on their peers' work. In Level 4 Module 2, students walk around the classroom to examine other groups' engineering solutions. They leave feedback for their peers on sticky notes and then reflect on feedback they received about their own solutions. Students are then given time to incorporate others' feedback in their designs. Teachers facilitate this process by posing questions to help students provide meaningful feedback.

Implementation Recommendations

- Display student artifacts, such as the driving question board, anchor model, and anchor chart, around the classroom to keep the products of student ideas visible.
- Foster a classroom culture that encourages students to ask questions at any time, not just when prompted. Connect student-generated language to Phenomenon Questions as often as possible.
- Allow students to lead discussion groups.
- Use a variety of cooperative learning routines, and review the effectiveness of the routine after each activity. (See Resources: Instructional Routines for more information.)
- Assign roles for each student during group activities. Periodically rotate roles to ensure that all students have the opportunity to grow in each role.

SPECIALIZED LANGUAGE DEVELOPMENT

Research Says	*PhD Science* Responds
"ELs [English learners] develop STEM knowledge and language proficiency when they are engaged in meaningful interaction in the classroom that includes participation in the kinds of activities in which STEM experts and professionals regularly engage. Whereas there is no language without content, there is some content that is less dependent on language. STEM subjects afford opportunities for alternate routes to knowledge acquisition (i.e., experimentation, demonstration of phenomena, and demonstration of practices) through which students can gain a sense of STEM content without resorting predominantly to language to access meaning—it is through this experience that language is also learned" (National Academies of Sciences, Engineering, and Medicine 2018, 2). "A review of the evidence on instructional strategies suggests that teachers of ELs who effectively engage with these students are more likely to understand that language is learned through meaningful and active engagement by ELs with language in the context of authentic STEM activities and practices. They encourage ELs to draw on their full range of linguistic and communicative competencies and resources while guiding them toward a focus on STEM meaning-making" (National Academies of Sciences, Engineering, and Medicine 2018, 3). "By designing instruction in specific ways—such as attending to disciplinary language demands, tapping into background knowledge, providing visuals and graphic organizers, or grouping students by linguistic background—teachers provide students with equitable access to learning while simultaneously supporting and promoting language development" (Heineke and McTighe 2018, 26).	With *PhD Science,* students engage in hands-on investigations and analyze evidence to build conceptual understanding of science ideas. Through these experiences, students often develop ideas by using everyday language before applying precise scientific language. This strategy allows all students to clarify their ideas and deepen their reasoning, and it is particularly beneficial for English learners who have been unable to fully participate previously because of the "vocabulary-first" approach traditional science curricula often uses. Great Minds believes that complex scientific language and vocabulary terms are not a prerequisite for conceptual understanding but rather a product of it. To this end, students develop understanding of a science idea first and are then introduced to precise terminology they can use to represent that idea. After students learn terminology in a meaningful context, *PhD Science* supports language development through a variety of practices, including explicit introduction to scientific language, sentence frames, collaborative conversations, and graphic organizers. (See Going Deeper: English Language Development for more information on how *PhD Science* supports students' language development.)

Examples in *PhD Science*

- Inside–Outside Circles is a collaborative conversation routine that allows students to respond to questions or discuss information in a structured manner.
  - In Level K Module 1, students participate in an Inside–Outside Circles routine to share their experiences with severe weather and to describe how they think meteorologists predict severe weather.
- Act It Out is a terminology learning routine that provides students with a kinesthetic outlet to connect movement with an unfamiliar term to remember its meaning.
  - In Level 2 Module 1, students use an Act It Out routine to demonstrate their understanding of the term *reversible change*. Students use their bodies to act out what it looks like for a solid to melt into a liquid and then freeze back into a solid. Students then discuss with their peers how they acted out melting and freezing.
- Frayer models help students represent their understanding of key science terms. Students provide the definition, characteristics, examples, and nonexamples of the term.
  - In Level 3 Module 1, students use a Frayer model to show their understanding of *climate*, a key term related to the module's knowledge goals. The *PhD Science* Teacher Edition provides follow-up suggestions for teachers to help students better distinguish between *climate* and *weather*.
- Sentence frames appear throughout a module to support students' ability to communicate ideas about their science learning.
  - In Level 3 Module 4, students use the "When ______, then ______." sentence frame to explain the cause and effect relationships they observe when working with magnets.
- The Teacher Edition provides English Language Development notes for teachers, which include Spanish cognates and best practices for supporting English learners.

Implementation Recommendations

- Encourage students to develop conceptual understanding by using home or everyday language to explain concepts.
- Provide in-the-moment language supports as needed, including modeling, demonstrations, graphic and sensory supports, and sentence frames.
- When appropriate, assign English learners to small groups of students who share the same native language.
- Consider the academic words students will use throughout each module and how those words relate to other content areas. Create a word wall with words that connect the SEPs and CCs to related terms in English language arts and mathematics.

CULTURAL PLURALISM

Research Says	***PhD Science* Responds**
“The pursuit of equity in education requires detailed attention to the circumstances of specific demographic groups. When appropriate and relevant to the science issue at hand, standards documents should explicitly represent the cultural particulars of diverse learning populations throughout the text (e.g., in referenced examples, sample vignettes, performance expectations). Similarly, an effort should be made to include significant contributions of women and of people from diverse cultures and ethnicities” (NRC 2012, 288).	*PhD Science* represents diverse cultures and backgrounds through phenomena, media, texts, and tasks. Anchor phenomena are carefully chosen to be not only knowledge-rich but also culturally rich. The anchor phenomena in *PhD Science* are set in diverse communities and locations around the globe. Additionally, students reflect on the current and historical cultural implications of the science knowledge they build throughout the module. They accomplish this reflection by interacting with authentic resources that relate to the module’s phenomena, including photographs, videos, trade books, and historical primary sources. Modules often include rich stories that situate phenomena and the science ideas behind them in a cultural context and describe individual scientists’ multifaceted experiences and identities. These stories invite multiple points of connection with phenomena and scientists. A unique aspect of the *PhD Science* curriculum is the integration of art. Art and science both begin with wonder, inviting students to observe, question, and make sense of the world around them. Each module integrates a purposefully selected art piece. Students interact with this art to engage with a phenomenon through artistic representation, explore the art itself as a phenomenon, or apply their science knowledge in unexpected contexts. These pieces, by artists from diverse backgrounds and cultures, invite students to connect various cultural experiences to science in new ways. Finally, *PhD Science* invites students to bring their own cultural backgrounds and experiences to the classroom through related phenomena. Students share related phenomena when they first interact with an anchor phenomenon. Throughout the module, students have the opportunity to make sense of the related phenomena, making the science ideas they are learning relevant to their personal experiences.

Examples in *PhD Science*

- *PhD Science* anchor phenomena represent a wide array of science topics from across the globe. Students are also encouraged to think about local applications of these scientific phenomena.
    - In Level 1 Module 2, students learn about wayang kulit, an Indonesian shadow puppet show. Students watch videos of wayang shows and wonder how puppeteers use light to tell stories. Throughout the module, students apply their learning about light to explain how light interacts with different parts of a wayang show to allow a puppeteer to tell a story.
    - In Level 2 Module 4, students learn about the varied environments of the Mount Everest region. Throughout the module, students explore biomes by looking for patterns in weather data and in the variety of life in different areas around the world. In the Science Challenge, students apply what they have learned to their local environment as they measure and describe the biodiversity of their schoolyard.
    - In Level 4 Module 3, students encounter the anchor phenomenon of elephants sensing rainstorms from many miles away through the book *The Elephant Scientist* by Dr. Caitlin O'Connell and Donna Jackson (2011). Throughout the module, students use Dr. O'Connell's work as an access point to the content. Students go on to relate the anchor phenomenon to ways in which other organisms, including humans, sense information.
    - In Level 5 Module 3, students study Balinese rice farming systems. Students then relate this phenomenon to local issues such as food supply and the availability of clean drinking water.
    - In Level 5 Module 4, students make sense of their firsthand observations of the sky from Earth. They study how ancient Polynesians used patterns in the motion of the Sun, the Moon, and stars to navigate to distant islands in the Pacific Ocean.

- Trade books used in *PhD Science* represent a variety of cultural perspectives. The inclusion of a wide variety of subjects and authors allows students to engage with many different science topics and experts.
    - In Level 1 Module 4, students read *Island Below the Star* (Rumford 2012), which is a fictional story inspired by early Polynesian navigators who sailed from the Marquesas Islands to the Hawaiian Islands without compasses or maps. By reading this story, students find out how early navigators used the weather, animals, the Sun, the Moon, and the stars to travel across the open ocean.
    - In Level 4 Module 2, students learn the story of William Kamkwamba—a boy in Malawi who built a windmill to help the people of his village—in *The Boy Who Harnessed the Wind* (Kamkwamba and Mealer 2010).
    - In Level 5 Module 2, students read *The Mangrove Tree* (Roth and Trumbore 2011) to learn how Dr. Gordon Sato led a project planting mangrove trees in Eritrea to spark the development of a rich, sustainable ecosystem capable of providing people with food and resources.
    - In Level 5 Module 4, students read *Look Up!: Henrietta Leavitt, Pioneering Woman Astronomer* (Burleigh 2013) and learn how Leavitt was the first person to identify the significance of a star's brightness despite working in a field dominated by men.

- To prepare for Engineering Challenges, students discuss the strategies of historical and contemporary engineers from diverse backgrounds to deepen their knowledge of the engineering design process.
    - In Level 3 Module 1, reading Emily Arnold McCully's book *Marvelous Mattie: How Margaret E. Knight Became an Inventor* (2006) gives students the opportunity to learn about and make personal connections with an inventor.

- Modules provide resources for teachers to support students with diverse backgrounds and experiences as they engage in science learning.
    - Level 1 Module 3 includes a resource with guidelines on how to adapt the Engineering Challenge so that it is more accessible and inclusive for students who are deaf or hard of hearing.
    - Level 3 Module 3 presents a discussion of trait inheritance with diverse examples of human physical traits to support teachers in facilitating inclusive, positive discussions of these diverse traits.

Implementation Recommendations

- Support students in sharing and making sense of related phenomena that connect to their personal experiences, interests, and beliefs.
- Invite students' families and community members to share experiences and expertise related to module phenomena and concepts. Connect students with these individuals through field trips, guest speakers, letter writing, video conferences, and other events.
- Encourage students to share personal stories, experiences, and interests that relate to their science learning.
- Provide additional resources and materials related to module content that describe the experiences, ideas, and contributions of scientists, engineers, and other individuals from diverse cultures and backgrounds, especially those that connect with students' identities.

Scope and Sequence of NGSS

Curriculum Maps

PhD Science modules are sequenced to build coherent student understanding of science ideas, SEPs, and CCs within and across levels and should be taught in the recommended order. Modules provide opportunities for students to explore questions and apply knowledge and skills they developed in previous modules. Each module's Teacher Edition describes how student understanding progresses across modules, such as in the Building Knowledge and Skills Across Levels section of the Module Overview and the Spotlight on Three-Dimensional Integration notes within lesson sets.

The curriculum maps provide an at-a-glance view of module titles, anchor phenomena, and focus Performance Expectations (PEs) for each level.

Levels K–2

LEVEL K	Title	Anchor Phenomenon	Performance Expectations
Module 1	▲ Weather	Cliff Dwellings at Mesa Verde	K-ESS2-1; K-ESS3-2; K-PS3-1; K-PS3-2; K–2-ETS1-1
Module 2	■ Pushes and Pulls	Tugboats Moving Cargo Ships	K-PS2-1; K-PS2-2; K–2-ETS1-2
Module 3	● Life	Life in the Mojave Desert	K-LS1-1; K-ESS3-1
Module 4	▲ Environments	Life in a Longleaf Pine Forest	K-ESS2-2; K-ESS3-3

LEVEL 1	Title	Anchor Phenomenon	Performance Expectations
Module 1	● Survival	Life at a Pond	1-LS1-1; 1-LS1-2; 1-LS3-1; K–2-ETS1-1
Module 2	■ Light	Wayang Shadow Puppetry	1-PS4-2; 1-PS4-3
Module 3	■ Sound	The Recycled Orchestra of Cateura	1-PS4-1; 1-PS4-4; K–2-ETS1-2; K–2-ETS1-3
Module 4	▲ Sky	Polynesian Navigation	1-ESS1-1; 1-ESS1-2

LEVEL 2	Title	Anchor Phenomenon	Performance Expectations
Module 1	■ Matter	Birds Building Nests	2-PS1-1; 2-PS1-2; 2-PS1-3; 2-PS1-4; K–2-ETS1-1
Module 2	▲ Earth Changes	Transformation of Surtsey	2-ESS1-1; 2-ESS2-1; K–2-ETS1-3
Module 3	● Plants	Plant Recovery Around Mount St. Helens	2-LS2-1; 2-LS2-2; K–2-ETS1-2
Module 4	● Biomes	Varied Environments of the Mount Everest Region	2-LS4-1; 2-ESS2-2; 2-ESS2-3

▲ Earth and Space Science (ESS) Focus
● Life Science (LS) Focus
■ Physical Science (PS) Focus

Levels 3–5

LEVEL 3	Title	Anchor Phenomenon	Performance Expectations
Module 1	▲ Weather and Climate	1900 Galveston Hurricane	3-ESS2-1; 3-ESS2-2; 3-ESS3-1; 3-5-ETS1-1
Module 2	● Survival	Butterfly Survival	3-LS2-1; 3-LS4-1; 3-LS4-3; 3-LS4-4; 3-5-ETS1-2
Module 3	● Traits	Individual Variation in Humpback Whales	3-LS1-1; 3-LS3-1; 3-LS3-2; 3-LS4-2
Module 4	■ Forces and Motion	Motion in Outer Space	3-PS2-1; 3-PS2-2; 3-PS2-3; 3-PS2-4; 3-5-ETS1-3

LEVEL 4	Title	Anchor Phenomenon	Performance Expectations
Module 1	▲ The Changing Earth	Grand Canyon Features and Patterns	4-ESS1-1; 4-ESS2-1; 4-ESS2-2; 4-ESS3-1; 4-ESS3-2; 3-5-ETS1-2
Module 2	■ Energy	Windmills at Work	4-PS3-1; 4-PS3-2; 4-PS3-3; 4-PS3-4; 3-5-ETS1-1
Module 3	● Sense and Response	Elephants Sensing Distant Rainstorms	4-LS1-1; 4-LS1-2; 4-PS4-1
Module 4	■ Light	Visibility of and Communication to Howland Island	4-PS4-2; 4-PS4-3; 3-5-ETS1-2; 3-5-ETS1-3

LEVEL 5	Title	Anchor Phenomenon	Performance Expectations
Module 1	■ Matter	Changes to the Statue of Liberty's Appearance	5-PS1-1; 5-PS1-2; 5-PS1-3; 5-PS1-4; 3-5-ETS1-3
Module 2	● Ecosystems	Life Around a Mangrove Tree	5-LS1-1; 5-LS2-1; 5-PS3-1; 3-5-ETS1-1
Module 3	▲ Earth Systems	Balinese Rice Farming	5-ESS2-1; 5-ESS2-2; 5-ESS3-1; 3-5-ETS1-2
Module 4	▲ Orbit and Rotation	Views from Earth and Space	5-ESS1-1; 5-ESS1-2; 5-PS2-1

▲ Earth and Space Science (ESS) Focus ● Life Science (LS) Focus ■ Physical Science (PS) Focus

Performance Expectations and Disciplinary Core Ideas

The following tables provide an at-a-glance view of the PEs that serve as the focus of instruction and assessment in each module. The DCI element(s) associated with a PE are always a focus in the corresponding module.‡

Level K

NGSS	Mod 1	Mod 2	Mod 3	Mod 4
K-PS2-1		●		
K-PS2-2		●		
K-PS3-1	●			
K-PS3-2	●			
K-LS1			●	
K-ESS2-1	●			
K-ESS2-2				●
K-ESS3-1			●	
K-ESS3-2	●			
K-ESS3-3				●
K-2-ETS1-1	●			
K–2-ETS1-2		●		

Level 1

NGSS	Mod 1	Mod 2	Mod 3	Mod 4
1-PS4-1			●	
1-PS4-2		●		
1-PS4-3		●		
1-PS4-4			●	
1-LS1-1	●			
1-LS1-2	●			
1-LS3	●			
1-ESS1-1				●
1-ESS1-2				●
K-2-ETS1-1	●			
K–2-ETS1-2			●	
K–2-ETS1-3			●	

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‡ For more information on focus Science and Engineering Practices and Crosscutting Concepts, see the relevant sections below. In agreement with the Next Generation Science Standards' guidance (NGSS Lead States 2013), students may focus on Science and Engineering Practices and Crosscutting Concepts other than those named in a focus Performance Expectation.

Level 2

NGSS	Mod 1	Mod 2	Mod 3	Mod 4
2-PS1-1	●			
2-PS1-2	●			
2-PS1-3	●			
2-PS1-4	●			
2-LS2-1			●	
2-LS2-2			●	
2-LS4				●
2-ESS1		●		
2-ESS2-1		●		
2-ESS2-2				●
2-ESS2-3				●
K–2-ETS1-1	●			
K–2-ETS1-2			●	
K–2-ETS1-3		●		

Level 3

NGSS	Mod 1	Mod 2	Mod 3	Mod 4
3-PS2-1				●
3-PS2-2				●
3-PS2-3				●
3-PS2-4				●
3-LS1			●	
3-LS2		●		
3-LS3-1			●	
3-LS3-2			●	
3-LS4-1		●		
3-LS4-2			●	
3-LS4-3		●		
3-LS4-4		●		
3-ESS2-1	●			
3-ESS2-2	●			
3-ESS3	●			
3–5-ETS1-1	●			
3–5-ETS1-2		●		
3–5-ETS1-3				●

Level 4

NGSS	Mod 1	Mod 2	Mod 3	Mod 4
4-PS3-1		●		
4-PS3-2		●		
4-PS3-3		●		
4-PS3-4		●		
4-PS4-1			●	
4-PS4-2				●
4-PS4-3				●
4-LS1-1			●	
4-LS1-2			●	
4-ESS1	●			
4-ESS2-1	●			
4-ESS2-2	●			
4-ESS3-1	●			
4-ESS3-2	●			
3-5-ETS1-1		●		
3-5-ETS1-2	●			●
3-5-ETS1-3				●

Level 5

NGSS	Mod 1	Mod 2	Mod 3	Mod 4
5-PS1-1	●			
5-PS1-2	●			
5-PS1-3	●			
5-PS1-4	●			
5-PS2				●
5-PS3		●		
5-LS1		●		
5-LS2		●		
5-ESS1-1				●
5-ESS1-2				●
5-ESS2-1			●	
5-ESS2-2			●	
5-ESS3			●	
3-5-ETS1-1		●		
3-5-ETS1-2			●	
3-5-ETS1-3	●			

Science and Engineering Practices

A Framework for K–12 Science Education and the NGSS identify eight SEPs:

SEP.1: Asking Questions and Defining Problems

SEP.2: Developing and Using Models

SEP.3: Planning and Carrying Out Investigations

SEP.4: Analyzing and Interpreting Data

SEP.5: Using Mathematics and Computational Thinking

SEP.6: Constructing Explanations and Designing Solutions

SEP.7: Engaging in Argument from Evidence

SEP.8: Obtaining, Evaluating, and Communicating Information

FOCUS SCIENCE AND ENGINEERING PRACTICES

Each *PhD Science* module uses a combination of SEPs throughout to help students make sense of phenomena and develop science ideas. When a module identifies an SEP as a focus, the SEP plays a major role in students' explanation of a phenomenon or solution to a problem. While focus SEPs are central to sense-making in a module, they are not the only SEPs students encounter.

Levels K–2

LEVEL K	SEP.1	SEP.2	SEP.3	SEP.4	SEP.5	SEP.6	SEP.7	SEP.8
Module 1	●	●	●		●			
Module 2	●		●	●	●			
Module 3	●	●	●	●		●	●	
Module 4				●			●	●

LEVEL 1	SEP.1	SEP.2	SEP.3	SEP.4	SEP.5	SEP.6	SEP.7	SEP.8
Module 1	●	●		●		●		
Module 2		●	●	●	●			
Module 3			●	●				
Module 4							●	●

LEVEL 2	SEP.1	SEP.2	SEP.3	SEP.4	SEP.5	SEP.6	SEP.7	SEP.8
Module 1		●	●	●		●		
Module 2		●	●		●	●	●	●
Module 3		●	●		●		●	●
Module 4		●			●		●	●

Levels 3–5

LEVEL 3	SEP.1	SEP.2	SEP.3	SEP.4	SEP.5	SEP.6	SEP.7	SEP.8
Module 1	●			●	●			●
Module 2		●		●		●	●	
Module 3		●		●		●		
Module 4	●	●	●	●		●		

LEVEL 4	SEP.1	SEP.2	SEP.3	SEP.4	SEP.5	SEP.6	SEP.7	SEP.8
Module 1		●	●	●		●		●
Module 2	●	●	●			●		
Module 3	●	●	●			●	●	●
Module 4		●	●			●		

LEVEL 5	SEP.1	SEP.2	SEP.3	SEP.4	SEP.5	SEP.6	SEP.7	SEP.8
Module 1		●	●	●	●	●		
Module 2	●	●	●	●		●	●	●
Module 3		●		●	●	●		●
Module 4		●				●	●	

Crosscutting Concepts

A Framework for K–12 Science Education and the NGSS identify seven CCs:

CC.1: Patterns

CC.2: Cause and Effect

CC.3: Scale, Proportion, and Quantity

CC.4: Systems and System Models

CC.5: Energy and Matter

CC.6: Structure and Function

CC.7: Stability and Change

FOCUS CROSSCUTTING CONCEPTS

CCs are used in combination throughout each *PhD Science* module to help students make sense of phenomena and develop science ideas. When a CC is identified as a focus in a module, it plays a major role in students' explanation of a phenomenon or solution to a problem. It is important to note that while focus CCs are central to sense-making in a module, they are not the only CCs students encounter.

Levels K–2

LEVEL K	CC.1	CC.2	CC.3	CC.4	CC.5	CC.6	CC.7
Module 1	●		●			●	●
Module 2	●	●	●				
Module 3	●			●			
Module 4		●					

LEVEL 1	CC.1	CC.2	CC.3	CC.4	CC.5	CC.6	CC.7
Module 1	●					●	
Module 2	●	●		●			
Module 3	●			●			
Module 4	●	●					

LEVEL 2	CC.1	CC.2	CC.3	CC.4	CC.5	CC.6	CC.7
Module 1	●	●		●		●	
Module 2			●	●	●		●
Module 3		●	●	●		●	
Module 4	●		●	●			

Levels 3–5

LEVEL 3	CC.1	CC.2	CC.3	CC.4	CC.5	CC.6	CC.7
Module 1	●	●	●				●
Module 2	●	●		●		●	
Module 3	●	●				●	
Module 4	●	●		●			

LEVEL 4	CC.1	CC.2	CC.3	CC.4	CC.5	CC.6	CC.7
Module 1	●	●	●	●			●
Module 2	●	●		●	●		
Module 3	●	●		●	●	●	
Module 4	●	●		●		●	

LEVEL 5	CC.1	CC.2	CC.3	CC.4	CC.5	CC.6	CC.7
Module 1		●	●	●	●		●
Module 2	●	●	●	●	●		●
Module 3		●	●	●			●
Module 4	●			●			●

Connections to Nature of Science

In *PhD Science* Levels K–5, students explicitly engage with, develop, and use the elements of understanding associated with the nature of science. The tables below identify these elements and the modules where each is integrated.

Levels K–2

ELEMENT	K M1	K M2	K M3	K M4	1 M1	1 M2	1 M3	1 M4	2 M1	2 M2	2 M3	2 M4
Scientific Investigations Use a Variety of Methods • Scientific investigations begin with a question.	●			●		●						
• Scientists use different ways to study the world.		●						●				
Scientific Knowledge Is Based on Empirical Evidence • Scientists look for patterns and order when making observations about the world.			●		●	●						●
Scientific Knowledge Is Open to Revision in Light of New Evidence • Scientific knowledge can change when new information is found.							●					●
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena • Scientists use drawings, sketches, and models as a way to communicate ideas.				●				●		●		
• Scientists search for cause and effect relationships to explain natural events.		●				●				●		
Science Is a Way of Knowing • Scientific knowledge informs us about the world.		●		●								
Scientific Knowledge Assumes an Order and Consistency in Natural Systems • Science assumes natural events happen today as they happened in the past.	●							●		●		
• Many events are repeated.	●							●				
Science Is a Human Endeavor • People have practiced science for a long time.			●					●				
• Men and women of diverse backgrounds are scientists and engineers.			●									
Science Addresses Questions About the Natural and Material World • Scientists study the natural and material world.	●	●	●	●	●	●	●	●	●	●	●	●

Levels 3–5

ELEMENT	3 M1	3 M2	3 M3	3 M4	4 M1	4 M2	4 M3	4 M4	5 M1	5 M2	5 M3	5 M4
Scientific Investigations Use a Variety of Methods • Scientific methods are determined by questions.				●								●
• Scientific investigations use a variety of methods, tools, and techniques.				●						●		
Scientific Knowledge Is Based on Empirical Evidence • Scientific findings are based on recognizing patterns.			●	●			●					●
• Scientists use tools and technologies to make accurate measurements and observations.												●
Scientific Knowledge Is Open to Revision in Light of New Evidence • Scientific explanations can change based on new evidence.												●
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena • Scientific theories are based on a body of evidence and many tests.				●								
• Scientific explanations describe the mechanisms for natural events.										●		●
Science Is a Way of Knowing • Science is both a body of knowledge and processes that add new knowledge.											●	
• Science is a way of knowing that is used by many people.			●									
Scientific Knowledge Assumes an Order and Consistency in Natural Systems • Science assumes consistent patterns in natural systems.		●			●				●			
• Basic laws of nature are the same everywhere in the universe.												●
Science Is a Human Endeavor • Men and women from all cultures and backgrounds choose careers as scientists and engineers.			●									
• Most scientists and engineers work in teams.			●			●						
• Science affects everyday life.	●					●						
• Creativity and imagination are important to science.											●	
Science Addresses Questions About the Natural and Material World • Scientific findings are limited to what can be answered with empirical evidence.											●	●

Connections to Engineering, Technology, and Applications of Science

In *PhD Science* Levels 3–5, students explicitly engage with, develop, and use the elements of understanding associated with engineering, technology, and applications of science. The tables below identify these elements and the modules where each is integrated.

Levels K–2

ELEMENT	K M1	K M2	K M3	K M4	1 M1	1 M2	1 M3	1 M4	2 M1	2 M2	2 M3	2 M4
Interdependence of Science, Engineering, and Technology • People encounter questions about the natural world every day.			●	●								
• Science and engineering involve the use of tools to observe and measure things.											●	
Influence of Engineering, Technology, and Science on Society and the Natural World • Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials.				●	●					●	●	
• Developing and using technology has impacts on the natural world.				●						●		
• People depend on various technologies in their lives; human life would be very different without technology.				●			●			●		

Levels 3–5

ELEMENT	3 M1	3 M2	3 M3	3 M4	4 M1	4 M2	4 M3	4 M4	5 M1	5 M2	5 M3	5 M4
Interdependence of Science, Engineering, and Technology • Science and technology support each other.				●								
• Knowledge of relevant scientific concepts and research findings is important in engineering.		●			●			●				
• Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process.				●								
• Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies.												●
Influence of Engineering, Technology, and Science on Society and the Natural World • People's needs and wants change over time, as do their demands for new and improved technologies.	●				●	●				●		
• Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands.		●			●	●		●		●	●	
• When new technologies become available, they can bring about changes in the way people live and interact with one another.				●								

Resources

Supporting Scientific Discourse

CLASSROOM EXPECTATIONS

Scientific discourse is integral to the NGSS and requires a classroom environment where all students productively share their ideas and questions. As students make sense of phenomena, they develop science ideas while engaging in the SEPs and using the lens of the CCs. During every step of the learning process, students must have the opportunity to process information. They accomplish this when they clarify, justify, and interpret their ideas through discussion, allowing them to deepen their reasoning. Students engage in multiple practices as they gather evidence and make sense of phenomena. Discourse is the sense-making tool used with each practice that allows students to put the pieces of evidence together to develop scientific understanding.

During science discussions, remind students of classroom expectations for discourse, including the Speaking and Listening Anchor Standards and their grade-level counterparts (NGA Center, CCSSO 2010)[§] as listed below.

Comprehension and Collaboration

- CCSS.ELA-Literacy.CCRA.SL.1: Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.
- CCSS.ELA-Literacy.CCRA.SL.2: Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
- CCSS.ELA-Literacy.CCRA.SL.3: Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric.

Presentation of Knowledge and Ideas

- CCSS.ELA-Literacy.CCRA.SL.4: Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.
- CCSS.ELA-Literacy.CCRA.SL.5: Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.
- CCSS.ELA-Literacy.CCRA.SL.6: Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.

[§] *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects* © Copyright 2010 National Governors Association Center for Best Practices and Council of Chief State School Officers. All rights reserved.

COLLABORATIVE CONVERSATION PROMPTS

During classroom conversations, use prompts such as the following to support students' discourse. Encourage students to ask similar questions of their peers.

Clarification

- What do you mean by _____?
- Can you say more about that?
- Could you summarize that in your own words?
- What is your main point?
- What difference does that make?

Reasoning

- Why do you think that?
- How did you come to that conclusion?
- What do you think caused that?
- If what you said is true, then how do you explain _____?
- What is an alternative to _____?

Evidence

- What is your evidence?
- Could you give us an example?
- What observations or data support your thinking?
- How do you know?

Collaboration

- Who can summarize what _____ just said?
- Who can build on that idea?
- Do you agree with _____? Disagree with _____?
- Did _____ change your mind, or are you sticking with your original answer?
- Does anyone see this another way?
- How are these two ideas alike? How are they different?

For additional reading on science discussions in the classroom, see the NSTA article "Making Time for Science Talk" by Mark J. Gagnon and Sandra K. Abell (http://phdsci.link/1148) or *Talk Science Primer* by Sarah Michaels and Cathy O'Connor (http://phdsci.link/1149).

Frequently Used Tasks

Strategically planned tasks are embedded throughout a module with the purpose of asking students to apply one or more SEPs or CCs to a phenomenon. These open-ended tasks provide just enough support to facilitate the next step in learning. Students use the structure of the tasks to help them make meaning of the content as they build independence in the use of these tasks over time.

Category Sort

Purpose	**Categorization** supports students in thinking critically about the relationships between or patterns among concepts.
How It Works	1. Students receive a set of cards with a concept-related term or picture on each card. 2. Students sort the cards into categories. Categories may be assigned, or students may create them according to specified guidelines. 3. (Optional) Students develop a name and/or description for each category.

Cause and Effect Chart

Purpose	Using a cause and effect chart helps students identify **cause and effect** relationships between events.
How It Works	1. Students complete a chart to show the relationship between events. 2. The column headings may vary until students analyze data and realize the cause and effect relationship.

Claim, Evidence, and Reasoning

Purpose	Through the **Claim, Evidence, and Reasoning** structure, students communicate what they know and how they know it, using evidence to support their claims.
How It Works	1. Students develop a claim based on prior knowledge and/or available evidence. 2. Students provide evidence that supports what they know. 3. Students justify why or how their evidence supports their claim. 4. Students defend or revise their claim during scientific argumentation with peers.

Comparison Chart

Purpose	Students organize their ideas in a **comparison chart** as they consider similarities and differences between two or more objects to support their interpretation of data.
How It Works	1. Students are presented with two or more objects or images. 2. Students record similarities between the items. 3. Students record analogous differences between the items.

Develop a Model

Purpose	**Models** provide students with tools for thinking, making predictions, and making sense of phenomena.
How It Works	1. Students develop a model to represent their ideas about how or why a phenomenon happens. This model may take a variety of forms: a diagram, a drawing, a physical replica, a mathematical representation, an analogy, or a computer simulation. 2. Students include an explanation as part of the model. 3. (Optional) Students periodically update their initial models as they gather more evidence that helps explain the phenomenon.

Notice and Wonder Chart

Purpose	A **notice and wonder chart** allows students to organize their observations and questions about a phenomenon.
How It Works	1. Students create or use a two-column chart with one column labeled I Notice and the other labeled I Wonder. 2. Students record observations and/or inferences under the I Notice heading and questions under the I Wonder heading.

Observations and Inferences Organizer

Purpose	The **observations and inferences organizer** is a tool to help students organize their thinking and learn the difference between observations and inferences.
How It Works	1. Students record observations based on their senses. 2. Students record inferences based on those observations. 3. Students record questions based on their observations and/or inferences.

Student-Driven Investigation Plans

Purpose	**Student-driven investigation plans** support students' development and implementation of scientific investigations as they become more systematic and skillful in their methods.
How It Works	1. Students brainstorm ideas of how to test either a student-generated or teacher-provided scientific question. 2. As part of the process, students may make a prediction about the outcome of the future testing. 3. Students develop an investigation plan. 4. Students implement the investigation plan and record data. 5. Students analyze the data and develop a claim or explanation based on evidence from the data that answers the original scientific question.

Instructional Routines

An instructional routine is a classroom procedure that supports the development of content knowledge and academic skills in an engaging and active way. An instructional routine provides students with a structured approach to thinking about a topic, question, or idea while often getting them moving and interacting with each other. The routines suggested in *PhD Science* lessons help students think about science in different ways to build content knowledge, deepen understanding, and develop critical thinking skills. Instructional routines increase student engagement and provide practices to make students' thinking and learning visible.

The following tables describe routines that appear frequently in *PhD Science* lessons and are organized by the main purpose of the routine. Although lessons provide examples of how to use routines, teachers should use their expertise to select routines that meet students' needs for each lesson's tasks.

COLLABORATIVE CONVERSATION ROUTINES AND TECHNIQUES

Fishbowl

Purpose	Use the **Fishbowl** routine to model or practice behaviors such as asking thoughtful questions, listening attentively, and sharing ideas and/or tasks.
Grouping	Class
How It Works	1. Establish a purpose for the Fishbowl by directing students to focus their observations and learning on something specific. 2. Divide students into two groups: inside or outside the fishbowl. Outside students sit in a circle around inside students. Typically, more students are outside the fishbowl than in it. 3. Provide additional information or directions to those in the fishbowl as needed. 4. Ask students inside the fishbowl to engage in a collaborative task or discussion, while students outside observe. 5. Have students debrief through discussion and/or writing.

Inside–Outside Circles

Purpose	The **Inside–Outside Circles** routine allows students to respond to questions or talk about information with a variety of other students in a structured manner.
Grouping	Class, then pairs
How It Works	1. The class is divided in half. One half becomes the inside circle, and the other half forms the outside circle to create two concentric circles. 2. Students in the inside circle face students in the outside circle. 3. Students receive a topic or a question, or students prepare a question related to a concept. 4. Students in each pair (one student in the inside circle and one student in the outside circle) take turns answering the question or discussing the topic. 5. When they finish sharing, one circle rotates so students face new partners for a new question or topic.

Mix and Mingle

Purpose	The **Mix and Mingle** routine offers an active way for students to share ideas about a text or concept orally.
Grouping	Class, then pairs
How It Works	1. Students receive a topic or a question, or students prepare a question related to a concept. 2. Students circulate and then pair up with a peer and share their responses. 3. Students circulate to stand with a different peer and then discuss responses to the same question or a new question. Optional: Use of a cue such as music or chanting tells students when to stop circulating and pair up. Students may stand back-to-back with a partner, think about the question, and then turn to face their partner and discuss.

Question Corners

Purpose	The **Question Corners** routine allows students to express and support their claims.
Grouping	Groups, then class
How It Works	1. Students receive a debatable statement or question. 2. A response or opinion is posted in each corner of the classroom. Students move to the corner that best represents their opinion. 3. Students discuss the reasons they chose their corner. 4. After listening to one another's reasoning, students have the option of moving to another corner, but they must explain their rationale for moving.

Response Techniques

Purpose	**Response techniques** encourage class engagement while enabling teachers to conduct quick, formative assessments of student understanding.
Grouping	Class
How It Works	Pose a question, and then use a technique such as one of the following to elicit quick responses from a variety of students. • Equity sticks (recommended for open-ended questions): Randomly select a student's name from a container that holds all students' names on slips of paper or craft sticks. • Response cards (recommended for questions with a closed set of possible responses): Have students select a response from a set of preprinted response cards, and ask them to hold up their cards for the class to see. • Nonverbal signal (recommended for questions with a closed set of possible responses): Ask students to respond with a general signal (e.g., the American Sign Language [ASL] sign for yes or no) or a situation-specific signal (e.g., the ASL letter *P* when they hear details about a story's problem). To promote independent thinking, have students make the signals close to their chests. • Whiteboards (recommended for open-ended or closed questions with short written responses): Have students write responses on individual whiteboards or other erasable boards, and then ask them to hold up their responses for the class to see.

Socratic Seminar

Purpose	A **Socratic Seminar** is a student-led academic conversation. This routine allows students to use their speaking and listening skills to express and deepen their science content knowledge.
Grouping	Class
How It Works	1. Students prepare for dialogue by reviewing and reflecting on relevant materials or texts. 2. Students engage in prewriting to stimulate and organize thinking about the topic. 3. Students receive an opening question. 4. Students form a dialogue circle and engage in collaborative speaking and listening by using evidence from their resources. 5. Students receive prompts as needed to stimulate the dialogue. 6. Students complete a postwriting activity to answer questions such as What new knowledge did you gain? and How did your thinking change? 7. Students debrief the activity, reflecting on what went well and what needs improvement.

Tableau

Purpose	A **Tableau** allows students to visually and kinesthetically express understanding of a concept.
Grouping	Individuals, pairs, or groups, then class
How It Works	1. Students use their bodies and facial expressions to create a scene, or tableau, that represents a specific concept. 2. The students in the tableau freeze in place and do not speak. 3. A student outside of the tableau may narrate the scene for viewers. 4. Viewers may comment on how the tableau represents the concept.

Think–Pair–Share

Purpose	**Think–Pair–Share** allows individual students to consider their thoughts about a question and then collaboratively discuss the question with peers.
Grouping	Individuals, then pairs, then groups or class
How It Works	1. Students receive a thought-provoking question. 2. Students have a few minutes to think about the question. 3. Students share their thoughts with a partner. 4. Pairs share their thoughts with groups or the class. Not all students need to share in the larger group. Variations • Think–Pair: Students complete the same procedure without the group or class sharing. • Think–Pair–Square: Students conduct a Think–Pair and then join a second pair, sharing in groups of four. • Jot–Pair–Share: Students quickly jot down their thinking before sharing with a partner.

Value Line-Up

Purpose	**Value Line-Up** encourages students to organize and deepen their thinking about essential concepts as they demonstrate agreement or disagreement with a posed statement or point of view and expand their understanding by listening to classmates' beliefs.
Grouping	Class, then pairs
How It Works	1. A statement related to a module idea or concept is read aloud. 2. Students line up based on their level of agreement or disagreement with the statement. 3. The single line then folds in half, pairing students such that students who most disagree are partnered with those who most agree. 4. Partners discuss their individual positions.

Vote–Discuss–Revote

Purpose	A formative assessment tool, **Vote–Discuss–Revote** tracks students' thinking throughout a lesson or module through the use of voting, student-driven discussion, and then reevaluation of the initial vote.
Grouping	Individuals, pairs, groups, then class
How It Works	1. Students receive a question along with a small set of possible answers (three to six) related to a topic of study, including multiple answers that are partially correct or reflect common student misconceptions. One answer should be the "best" choice. 2. Students first vote individually and anonymously on a sticky note (or with polling technology). These votes are collected and recorded publicly. 3. Students discuss their answers with a partner and then potentially with a group before deciding whether to change their votes based on the arguments of others. 4. This routine may be completed in one class period, or the routine may be repeated in a subsequent class period after students have investigated the concept further.

Whip Around

Purpose	**Whip Around** serves as a quick check for understanding of each student's thinking or a culminating reflection on learning.
Grouping	Class
How It Works	1. Students receive an open-ended question. 2. Individual students jot down or think about their answers. 3. Students share their responses one after another until all students have shared their answers. 4. If students have written their answers, they can strike out answers that someone else says first.

WRITTEN RESPONSE ROUTINES

Chalk Talk

Purpose	**Chalk Talk** is a silent conversation that helps students organize their thinking and fosters universal participation.
Grouping	Groups or class
How It Works	1. Questions are written on the board or on sheets of chart paper. 2. Students respond to the questions, as well as to others' follow-up questions and responses, by writing directly under each question on the board or paper.

Gallery Walk

Purpose	**Gallery Walk** deepens engagement and understanding by allowing students to share their work with peers in a gallery setting.
Grouping	Individuals, pairs, or groups
How It Works	1. Work is posted around the room. The work can be group investigation plans, group Graffiti Walls, group models, or other work. 2. Students circulate, closely viewing the work. They write their observations or discuss them with peers. (Optional: Some students stand beside their own work, acting as docents to present it to viewers.) 3. Students debrief through discussion and/or writing.

Give One–Get One–Move On

Purpose	**Give One–Get One–Move On** engages all students in identifying and sharing key learning.
Grouping	Pairs
How It Works	1. Students record key ideas on index cards or sticky notes. 2. Students locate a partner and share their key ideas. 3. The announcement "Give One" tells students to swap ideas and "Get One" from another student. 4. The announcement "Move On" tells students to circulate again to find a new partner and explain the new idea to the new partner.

Graffiti Wall

Purpose	**Graffiti Wall** helps students organize and deepen their thinking as they collaboratively explore key concepts. This routine supports visual learners and promotes collective learning.
Grouping	Groups
How It Works	1. Groups receive a sheet of chart paper. 2. After investigating, reading, or discussing a task, students record their ideas and learning on the paper through symbols, illustrations, words or phrases, and quotations. Scaffolds may take the form of specifying a minimum or maximum number of symbols or phrases for students to record on the wall.

Quick Write

Purpose	**Quick Write** is a brief written response that helps students reflect on a topic and allows teachers to assess comprehension. It can be used at the beginning of a lesson as a warm-up, during the middle of a lesson in response to an idea or experience, or at the end of a lesson to summarize key ideas.
Grouping	Individuals
How It Works	1. Select a purpose for the writing that is tied to the content area. 2. Read the prompt to students. 3. Give students a short amount of time to jot down whatever comes to mind in response. 4. Have students share with others, or collect their ideas to inform teaching.

Snowball

Purpose	The **Snowball** routine allows students to predict, summarize, justify, explain, or practice critical thinking in response to a content-related question or prompt. This routine provides a low-risk engagement opportunity for students because responses are anonymous.
Grouping	Class
How It Works	1. Students anonymously write a response or answer to a prompt or question on a piece of paper. 2. Students crumple the paper into a “snowball.” 3. Students throw their snowballs across the room for a short time. 4. After students have thrown several snowballs, they select the one closest to them and prepare to share the response on the paper with the class.

Stop and Jot

Purpose	**Stop and Jot** allows individual written responses to texts or learning. This procedure provides ongoing assessment data for teachers and helps students track their thinking.
Grouping	Individuals, then pairs or class
How It Works	1. An oral cue or a visual symbol (e.g., stop sign, response box) prompts students to pause and respond to a question during a task. 2. Students write a brief response. 3. Students briefly discuss their responses with a partner and/or the whole class. 4. Students can refer to their Stop and Jots when completing formative assessments. Variation: Stop and Draw Rather than writing, younger students draw a quick sketch to represent their responses.

TERMINOLOGY LEARNING ROUTINES

Act It Out

Purpose	The **Act It Out** routine provides students with a kinesthetic outlet to connect movement with an unfamiliar term to remember its meaning.
Grouping	Individuals or pairs, then groups
How It Works	1. Students receive a term, individually or in pairs, that has been introduced in a lesson but may still be unfamiliar. 2. Students have 1 or 2 minutes to imagine how they might add movement to the term to help convey its meaning. 3. Students then take turns acting out their terms in groups.

Concept Map

Purpose	A **concept map** allows students to determine connections between multiple related terms.
Grouping	Individuals, pairs, or groups
How It Works	1. Students receive a set of related terms. 2. Students determine connections between the terms. 3. Students create a graphic organizer to represent the terms' relationships. The shape varies depending on the word relationships (e.g., Venn diagram, spoke wheel, flowchart).

Frayer Model

Purpose	A **Frayer model** helps students identify and define unfamiliar concepts and terms by looking at essential characteristics, examples, and nonexamples.
Grouping	Individuals, pairs, or groups
How It Works	1. A concept or term is selected for further study. 2. Students record the characteristics, examples, and nonexamples of the concept or term to create a working description or definition. As an extension activity, students can sketch their examples and nonexamples.

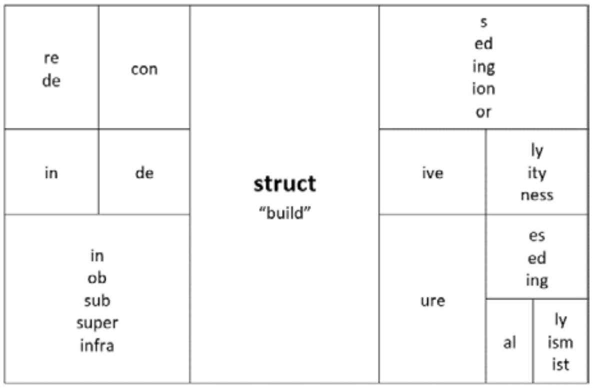
Link Up

Purpose	**Link Up** helps students understand the connection between two identified scientific terms.
Grouping	Pairs, then class
How It Works	1. Each student receives a card with a scientific term on it. 2. An (optional) demonstration of the routine helps students understand relationships that different terms may have to each other. 3. Students circulate and discuss with each person they meet whether their terms are related. 4. When students identify someone with a related term, they pair with that person. 5. As a class, students debrief. For example, pairs share the relationship between their terms.

Logical Analogies

Purpose	**Logical analogies** help students find connections between concepts or ideas by making analogies.
Grouping	Individuals, pairs, or groups
How It Works	1. Students receive a prompt (older students may come up with their own analogies independently) to complete related to a concept. 2. Students finish the analogy and share with classmates. Example A Veins are to _____ like _____ is/are to _____. Veins are to blood like roads are to cars. Most of the time everything moves smoothly, but sometimes they can get blocked. Example B Our nervous system is like <u>a tree with many branches</u>.

Morpheme Matrix

Purpose	A **morpheme matrix** deepens students' knowledge of roots and affixes. Use it to introduce a new term or to build on a known root.
Grouping	Individuals, pairs, or groups
How It Works	1. Introduce a term and encourage students to break the term down to its root(s) and affix(es). 2. Explicitly teach the meaning of the root(s) and/or affix(es). 3. Encourage students to brainstorm additional words that have the same root. Students create a morpheme matrix showing related words. 4. Discuss the meaning of new terms and use them in different contexts. Example: *reconstruct* 

Outside–In

Purpose	The **Outside–In** routine helps students determine word meaning from context and morphology such as roots and prefixes.
Grouping	Individuals, pairs, groups, or class
How It Works	1. Select an unfamiliar word from a text. 2. Ask students to discuss clues outside the word (context) that reveal the word's possible meaning. 3. Ask students to discuss what clues inside the word (e.g., roots, affixes) reveal about the word's possible meaning. 4. Have students draft possible definitions and then use reference materials to verify them.

Signal Unknown Words

Purpose	Students **signal unknown words** to build their understanding of scientific terminology.
Grouping	Pairs or individuals
How It Works	Students identify and annotate or record unknown words in a text, prioritizing those that are critical to their understanding of concepts.

TEXT-BASED ROUTINES

Choral Reading

Purpose	**Choral reading** supports fluency and comprehension of a challenging text.
Grouping	Class
How It Works	1. Provide copies of a text or project a large version at the front of the classroom. 2. Read a passage aloud to model fluent reading. Ask students to follow along with the text. They may place a piece of paper or an index card under each line to help them focus and keep their place. 3. Reread the passage as all students read the text aloud in unison.

Jigsaw

Purpose	The **Jigsaw** routine allows students to study one section of a text and then share with students who studied other sections. This strategy gives all students access to the ideas from the full text without requiring them to read the entire text. It also encourages collaborative learning.
Grouping	Groups
How It Works	1. A text is divided into sections. 2. Students form home groups with each student in a home group assigned a specific section of the text. 3. Students regroup according to their assignment from step 2, forming “expert” groups with others who share the same assignment. 4. Students work collaboratively in their expert groups to become experts on their assigned text. 5. Students then return to their home groups. One by one, group members share their expertise. Variation: One Stays, Three Stray Students from one Jigsaw group visit other groups and then report back to the Jigsaw group.

Partner Reading

Purpose	**Partner reading** is a cooperative activity that encourages peer-to-peer learning. It is a routine for fluency practice only when students have previously read the text.
Grouping	Pairs
How It Works	Option 1 1. Partner A reads the assigned passage while Partner B listens and comments on a specified aspect of the reading (e.g., accuracy or fluency). 2. Partner B reads the same passage while Partner A listens and comments. Option 2 1. Partner A reads a page, paragraph, or section. 2. Partner B reads a different page, paragraph, or section. 3. Each partner shares feedback after hearing the other read.

Save the Last Word

Purpose	The **Save the Last Word** routine helps students clarify and deepen their thinking about a text, quote, or idea while encouraging active speaking and listening skills. (Adapted from "The Final Word" by Jennifer Fischer-Mueller and Gene Thompson-Grove 2017.)
Grouping	Groups
How It Works	4. Students receive a quote, text, video clip, or other media that serves as the catalyst for this activity. 5. Students read/view the selection. 6. Students record three ideas or sentences that stood out to them on the front of an index card. On the back of the card, students write a brief explanation of why they selected those ideas (i.e., what the ideas mean to them or remind them of). 7. Working in groups of three, Student A reads one or more of the ideas on the front of the card. Students B and C discuss why those ideas might be important. Then Student A reads the back of the card to explain the reason for selecting the idea and thus has the "last word."

Socratic Seminar Resource

OVERVIEW

Socratic Seminars focus on the importance of questioning. Each seminar is based on a rigorous question that pushes students' thinking, allowing them to synthesize and extend their learning through exploration and debate. Students' conversations should go beyond summarizing learning from previous lessons.

STUDENT AND TEACHER ACTIONS

Student Actions

- Respond to peers, pose new questions, and offer new lines of inquiry.
- Practice and develop skills such as listening, responding, asking questions, paraphrasing, summarizing, citing evidence, making connections, and building ideas based on the opening question.

Teacher Actions

- Ask follow-up questions to elicit greater understanding of the topic, bring out viewpoints, draw out specifics, and so on. (See sample questions below.)
- Remain neutral by not affirming or challenging ideas, verbally or nonverbally. The goal is for students to think for themselves, not just agree because the teacher affirms something.
- Take notes for reflective practice and improvement.
- Debrief with the class after the seminar through questions such as the following:
  - How well did we meet our goals?
  - What worked?
  - What didn't work?

Facilitating an Effective Socratic Seminar

Facilitators listen attentively, sharing questions and observations only as needed. The facilitator (the teacher) asks the opening question and then observes as students initiate a discussion. If the initial question does not spark discussion, the teacher should encourage students to draw from their notes and prewriting. If significant wait time has passed, the teacher may consider asking a new question.

The facilitator's three early roles are as follows:

- Questioner: Ask an open-ended, thought-provoking question.
- Clarifier: Ask follow-up questions designed to increase clarity and specificity of responses.
- Process Coach: Coach students to go deeper, work together, build cohesion and rapport, and so on.

General facilitator actions include the following:

- Insist that answers are clear by directing students to rephrase as necessary.
- Insist on citations, text evidence, and strong reasoning.
- Put individual students "on hold" (i.e., pause them from speaking) to balance contributions.
- Invite additional viewpoints or opinions.

- Suggest a Think–Pair–Share.
- Track, tally, or map participation.

The facilitator may consider posing questions such as the following at opportune times to enhance collaboration:

- Do you agree with _____? Disagree with _____?
- Did _____ change your mind, or are you sticking with your original answer?
- Have you heard an answer that is different from yours?
- Does anyone see this another way?
- How are these two ideas alike? Different?
- Can you summarize what _____ just said?
- Does anyone have a different understanding of the problem?

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