

PhD Science®
TEKS Edition
Implementation Guide

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Introduction

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

Foundations

PhD Science TEKS Edition is an exemplary new science program from Great Minds PBC, the creators of *Eureka Math®* and *Wit & Wisdom®*. Designed for the Texas Essential Knowledge and Skills (TEKS) for science and English Language Proficiency Standards (ELPS) 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.

PhD Science TEKS Edition is available for Kindergarten to Grade 5. Each level consists of three or 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 participate in investigations, discussions, and activities that build enduring scientific understanding and competence. 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	<i>PhD Science</i> Responds
<p>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).</p> <p>“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).</p>	<p>Students need to be free to follow their curiosity to better understand the world around them.</p> <p>Students need to know how to participate in scientific discourse, ask challenging questions with clarity and precision, and respond to criticism.</p> <p>Students need to make claims, support their claims with evidence, elaborate on their ideas, and challenge the claims of others.</p>	<p>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.</p>
<p>“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).</p>	<p>Students need hands-on experiences that require the practical application of scientific processes.</p> <p>Students need time to observe, imagine, and reason.</p>	<p><i>PhD Science</i> 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.</p>

Research Says	Students Need	PhD Science Responds
<p>“As the <i>Framework</i> states, ‘knowledge and practice must be intertwined in designing learning experiences in K–12 science education’” (National Science Teaching Association [NSTA] 2018b, 1).</p> <p>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).</p>	<p>Students need learning experiences that allow them to see connections between scientific ideas, concepts, and practices.</p> <p>Students need learning experiences in a context that helps them make sense of phenomena and the world.</p> <p>Students need a coherent approach to studying science with clear connections among concepts and across levels.</p>	<p>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. Through this approach, students begin to see connections among scientific ideas, concepts, and practices as they apply their knowledge to understand phenomena and the world.</p>
<p>“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).</p> <p>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).</p>	<p>Students need time to study science with teachers who present it effectively.</p> <p>Students need opportunities to practice English language arts skills, mathematics skills, and skills from other content areas in a scientific context.</p>	<p><i>PhD Science</i> 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.</p>

Research Says	Students Need	PhD Science Responds
<p>“Assessment must be aligned with—</p> <ul style="list-style-type: none"> 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). 	<p>Students need meaningful and contextual assessments that allow them to apply scientific concepts to different phenomena.</p> <p>Students need purposeful assessments, whether diagnostic, formative, or summative.</p>	<p><i>PhD Science</i> 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.</p>

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 TEKS, key terms, information about the preparation of materials, safety considerations, a summary of knowledge built across levels, and professional resources for teachers.

Each module contains approximately 25–30 lessons organized into three or 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: Content-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 (Grades K–2) or 45-minute (Grades 3–5) lessons 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
- **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
- **Standards Addressed:** a summary of the focus standards (TEKS and ELPS) 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.

Icon	Title	Description
	Check for Understanding	Evaluation guidance for teachers, including evidence of student understanding and instructional next steps
	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 topics of study in English language arts/literacy
	Content Area Connection: Mathematics	Cross-curricular connections, instructional strategies, or additional activities that align with topics of study in 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 Knowledge and Skills	Explanation of how a lesson activity develops content, investigation, and reasoning skills
	Teacher Note	Additional educative information for teachers

Science Logbook

The Science Logbook is a consumable student resource. It enables students to record evidence and document their learning in the logbook. 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. 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 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 these phenomena prompt 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 a 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 developed 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 the Sense and Response module 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 the Energy module, 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 the Matter and Change module.
- **Everyday connection:** Phenomena allow students to make connections to their everyday lives and personal experiences. For example, experiences with local weather phenomena, such as rainstorms or tornadoes, can help students explain a massive historical hurricane in the Weather and Climate module.
- **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 the Orbit and Rotation module, students learn about an ancient Polynesian system of navigation in which people used observations of the Sun, Moon, and stars to help them navigate to distant islands.

Achieving the Standards

To achieve the TEKS for science, 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 discourse.

The Effect of Phenomenon-Driven Learning

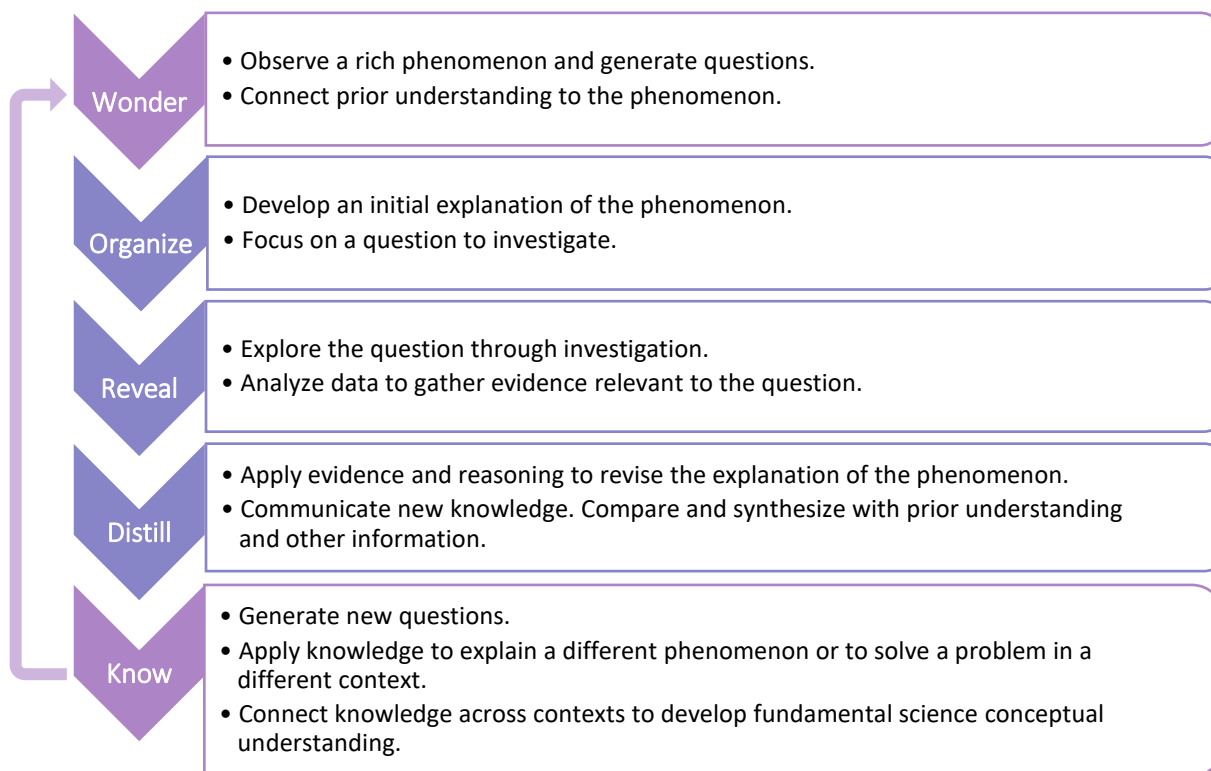
Throughout human history, natural phenomena have prompted questions and driven exploration. Bringing authentic phenomena into the classroom prepares students to question the world around them and gives them the tools necessary to apply their understanding to novel problems. Phenomenon-driven learning 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.



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 student-focused 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 five or seven E's to make sense of phenomena.

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

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

Content Stage	Student Actions	Strongly Related 7E Phases* (Teacher Actions)
Wonder	Asking Questions and Defining Problems	Elicit Engage
Organize	Developing and Using Models Constructing Explanations and Designing Solutions	Explore
Reveal	Planning and Carrying Out Investigations Analyzing and Interpreting Data Using Mathematics and Computational Thinking	Explore
Distill	Developing and Using Models Constructing Explanations and Designing Solutions Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information	Explain
Know	Asking Questions and Defining Problems Constructing Explanations and Designing Solutions	Elaborate Extend
<i>All</i>		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.

* 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 Grade 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 those listed in the Texas Education Agency—Texas Safety Standards (<http://phdsci.link/1575>).

- **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, consult the Texas Education Agency—Texas Safety Standards (<http://phdsci.link/1575>).

Materials

PhD Science's development of investigations and the 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.

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.

Materials for Grades K–5 have no special disposal requirements. When materials have such requirements, disposal protocols will be provided. 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).

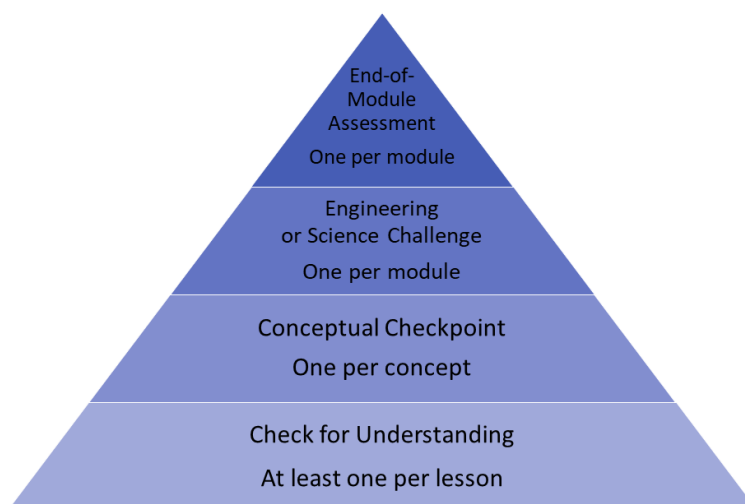
Going Deeper

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 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. The Assessment Support section can be used to assess student knowledge and skills and provide guidance on next steps to support students in reaching proficiency.

Throughout the 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 set (K–2) or lesson (3–5); 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

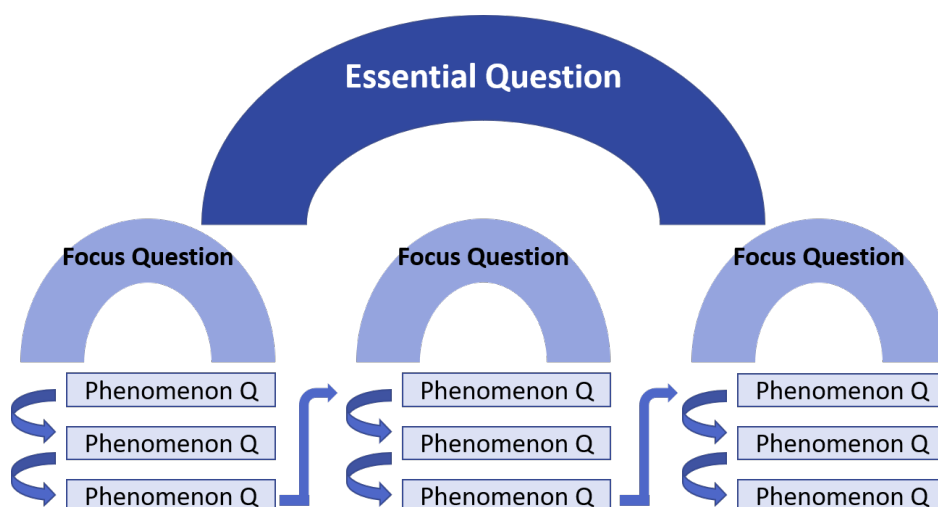
The following table summarizes how teachers facilitate students' work with anchor visuals.

Anchor Visual	Overview	How It Works
Driving Question Board	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.	<ol style="list-style-type: none"> 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	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.	<ol style="list-style-type: none"> 1. Students use their 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	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.	<ol style="list-style-type: none"> 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 or 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.
- Focus Questions anchor each concept sequence. By exploring each Focus Question, students build understanding related to the Essential Question.
- 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.



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: Speaking and Listening Supports 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.

English Language Development

While supporting language development is important for all students, it is especially important for English learners and nonstandard English speakers 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>) and the Texas Education Agency ELPS Resource Tools (<https://www.txel.org/elps/>).

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 Content-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 Echo Reading or 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.

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 a hands-on approach 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 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.
- 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.

† 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 create 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 science content

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 disabilities, 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.

Sequence and Routines

Curriculum Map

PhD Science modules are sequenced to build coherent student understanding of science ideas. Modules provide opportunities for students to explore questions and apply knowledge and skills they developed in previous modules.

This curriculum map is an at-a-glance view of module titles and anchor phenomena. This is the year one recommended sequence. In year two, modules will be realigned and new modules developed to ensure that content is covered but not repeated.

		Module 1	Module 2	Module 3	Module 4
Grade K	Title	Weather	Selected Topics	Selected Topics	Environments
	Anchor Phenomenon	Cliff Dwellings at Mesa Verde			Longleaf Pine Forest Ecosystem
Grade 1	Title	Weather	Survival	Selected Topics	Selected Topics
	Anchor Phenomenon	Cliff Dwellings at Mesa Verde	Life at a Pond		
Grade 2	Title	Survival	Matter	Selected Topics	Habitats
	Anchor Phenomenon	Life at a Pond	Birds Building Nests		Long Distance Migration of Osprey
Grade 3	Title	Weather and Climate	Survival and Change	Earth Changes	Forces and Motion
	Anchor Phenomenon	1900 Galveston Hurricane	Butterfly Survival	Transformation of Surtsey	Motion in Outer Space
Grade 4	Title	Earth Features	Energy	Ecosystems	Traits
	Anchor Phenomenon	Formation of the Grand Canyon's Features	Windmills at Work	Life around a Mangrove Tree	Individual Variation in Humpback Whales
Grade 5	Title	Earth Features	Energy	Ecosystems	Orbit and Rotation
	Anchor Phenomenon	Formation of the Grand Canyon's Features	Windmills at Work	Life around a Mangrove Tree	Views from Earth and Space

Supporting Scientific Discourse

Classroom Expectations

Scientific discourse is integral to the curriculum 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 habits of scientists. 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 as listed below.

Comprehension and Collaboration

- 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.
- Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
- Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric.

Presentation of Knowledge and Ideas

- 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.
- Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.
- Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.

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 (2007) (<http://phdsci.link/1148>) or *Talk Science Primer* by Sarah Michaels and Cathy O'Connor (2012) (<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 methods to understand 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.

Task	Purpose	How It Works
Category Sort	Categorization supports students in thinking critically about the relationships between or patterns among concepts.	<ol style="list-style-type: none"> 1. Students receive a set of cards with a concept-related term or picture on each card. 2. Students sort the index 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	Using a cause and effect chart helps students identify cause and effect relationships between events.	<ol style="list-style-type: none"> 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	Through the Claim, Evidence, and Reasoning structure, students communicate what they know and how they know it, using evidence to support their claims.	<ol style="list-style-type: none"> 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	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.	<ol style="list-style-type: none"> 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.

<p>Develop a Model</p>	<p>Models provide students with tools for thinking, making predictions, and making sense of phenomena.</p>	<ol style="list-style-type: none"> 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.
<p>Notice and Wonder Chart</p>	<p>A notice and wonder chart allows students to organize their observations and questions about a phenomenon.</p>	<ol style="list-style-type: none"> 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.
<p>Observations and Inferences Organizer</p>	<p>The observations and inferences organizer is a tool to help students organize their thinking and learn the difference between observations and inferences.</p>	<ol style="list-style-type: none"> 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.
<p>Student-Driven Investigation Plans</p>	<p>Student-driven investigation plans support students' development and implementation of scientific investigations as they become more systematic and skillful in their methods.</p>	<ol style="list-style-type: none"> 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

Routine	Purpose	Grouping	How It Works
Fishbowl	Use the Fishbowl routine to model or practice behaviors such as asking thoughtful questions, listening attentively, and sharing ideas and/or tasks.	Class	<ol style="list-style-type: none"> 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	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.	Class, then pairs	<ol style="list-style-type: none"> 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.

<p>Mix and Mingle</p>	<p>The Mix and Mingle routine offers an active way for students to share ideas about a text or concept orally.</p>	<p>Class, then pairs</p>	<ol style="list-style-type: none"> 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. <p>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.</p>
<p>Question Corners</p>	<p>The Question Corners routine allows students to express and support their claims.</p>	<p>Groups, then class</p>	<ol style="list-style-type: none"> 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.
<p>Response Techniques</p>	<p>Response techniques encourage class engagement while enabling teachers to conduct quick, formative assessments of student understanding.</p>	<p>Class</p>	<p>Pose a question, and then use a technique such as one of the following to elicit quick responses from a variety of students.</p> <ul style="list-style-type: none"> ▪ 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 <i>P</i> 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.

<p>Socratic Seminar</p>	<p>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.</p>	<p>Class</p>	<ol style="list-style-type: none"> 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.
<p>Think–Pair–Share</p>	<p>Think–Pair–Share allows individual students to consider their thoughts about a question and then collaboratively discuss the question with peers.</p>	<p>Individuals, then pairs, then groups or class</p>	<ol style="list-style-type: none"> 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. <p>Variations</p> <ul style="list-style-type: none"> ▪ 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.
<p>Value Line-Up</p>	<p>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.</p>	<p>Class, then pairs</p>	<ol style="list-style-type: none"> 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.
<p>Vote–Discuss–Revote</p>	<p>A formative assessment tool, Vote–Discuss–Revote tracks students’</p>	<p>Individuals, pairs,</p>	<ol style="list-style-type: none"> 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

	thinking throughout a lesson or module through the use of voting, student-driven discussion, and then reevaluation of the initial vote.	groups, then class	<p>misconceptions. One answer should be the “best” choice.</p> <ol style="list-style-type: none"> Students first vote individually and anonymously on a sticky note (or with polling technology). These votes are collected and recorded publicly. 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. 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	Whip Around serves as a quick check for understanding of each student’s thinking or a culminating reflection on learning.	Class	<ol style="list-style-type: none"> Students receive an open-ended question. Individual students jot down or think about their answers. Students share their responses one after another until all students have shared their answers. If students have written their answers, they can strike out answers that someone else says first.

Written Response Routines

Routine	Purpose	Grouping	How It Works
Chalk Talk	Chalk Talk is a silent conversation that helps students organize their thinking and fosters universal participation.	Groups or class	<ol style="list-style-type: none"> Questions are written on the board or on sheets of chart paper. 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	Gallery Walk deepens engagement and understanding by allowing students to share their work with peers in a gallery setting.	Individuals, pairs, or groups	<ol style="list-style-type: none"> Work is posted around the room. The work can be group investigation plans, group Graffiti Walls, group models, or other work. 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.) Students debrief through discussion and/or writing.
Give One–Get One–Move On	Give One–Get One–Move On engages all students in identifying and sharing key learning.	Pairs	<ol style="list-style-type: none"> Students record key ideas on index cards or sticky notes. Students locate a partner and share their key ideas.

			<ol style="list-style-type: none"> 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	Graffiti Wall helps students organize and deepen their thinking as they collaboratively explore key concepts. This routine supports visual learners and promotes collective learning.	Groups	<ol style="list-style-type: none"> 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	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.	Individuals	<ol style="list-style-type: none"> 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	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.	Class	<ol style="list-style-type: none"> 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	Stop and Jot allows individual written responses to texts or learning. This procedure provides ongoing assessment data for teachers and	Individuals, then pairs or class	<ol style="list-style-type: none"> 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.

	helps students track their thinking.		<p>4. Students can refer to their Stop and Jots when completing formative assessments.</p> <p>Variation: Stop and Draw</p> <p>Rather than writing, younger students draw a quick sketch to represent their responses.</p>
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Terminology Learning Routines

Routine	Purpose	Grouping	How It Works
Act It Out	The Act It Out routine provides students with a kinesthetic outlet to connect movement with an unfamiliar term to remember its meaning.	Individuals or pairs, then groups	<ol style="list-style-type: none"> 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	A concept map allows students to determine connections between multiple related terms.	Individuals, pairs, or groups	<ol style="list-style-type: none"> 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).
Framer Model	A Framer model helps students identify and define unfamiliar concepts and terms by looking at essential characteristics, examples, and nonexamples.	Individuals, pairs, or groups	<ol style="list-style-type: none"> 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. <p>As an extension activity, students can sketch their examples and nonexamples.</p>

<p>Link Up</p>	<p>Link Up helps students understand the connection between two identified scientific terms.</p>	<p>Pairs, then class</p>	<ol style="list-style-type: none"> 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. 																							
<p>Logical Analogies</p>	<p>Logical analogies help students find connections between concepts or ideas by making analogies.</p>	<p>Individuals, pairs, or groups</p>	<ol style="list-style-type: none"> 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. <p>Example A</p> <p>Veins are to _____ like _____ is/are to _____.</p> <p>Veins are to blood like roads are to cars. Most of the time everything moves smoothly, but sometimes they can get blocked.</p> <p>Example B</p> <p>Our nervous system is like <u>a tree with many branches</u>.</p>																							
<p>Morpheme Matrix</p>	<p>A morpheme matrix deepens students’ knowledge of roots and affixes. Use it to introduce a new term or to build on a known root.</p>	<p>Individuals, pairs, or groups</p>	<ol style="list-style-type: none"> 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. <p>Example: <i>reconstruct</i></p> <table border="1" data-bbox="841 1474 1338 1730"> <tr> <td>re</td> <td>con</td> <td rowspan="2" style="text-align: center;">struct "build"</td> <td colspan="2">s</td> </tr> <tr> <td>de</td> <td></td> <td>ed</td> <td>ing</td> </tr> <tr> <td>in</td> <td>de</td> <td></td> <td>ion</td> <td>or</td> </tr> <tr> <td colspan="3" rowspan="3" style="text-align: center;">in od sub super infra</td> <td>ive</td> <td>ly ity ness</td> </tr> <tr> <td rowspan="2">ure</td> <td>es ed ing</td> </tr> <tr> <td>al</td> <td>ly ism ist</td> </tr> </table>	re	con	struct "build"	s		de		ed	ing	in	de		ion	or	in od sub super infra			ive	ly ity ness	ure	es ed ing	al	ly ism ist
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Outside-In	The Outside-In routine helps students determine word meaning from context and morphology such as roots and prefixes.	Individuals, pairs, groups, or class	<ol style="list-style-type: none"> 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	Students signal unknown words to build their understanding of scientific terminology.	Pairs or individuals	Students identify and annotate or record unknown words in a text, prioritizing those that are critical to their understanding of concepts.

Text-Based Routines

Routine	Purpose	Grouping	How It Works
Choral Reading	Choral reading supports fluency and comprehension of a challenging text.	Class	<ol style="list-style-type: none"> 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	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.	Groups	<ol style="list-style-type: none"> 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. <p>Variation: One Stays, Three Stray Students from one Jigsaw group visit other groups and then report back to the Jigsaw group.</p>
Partner Reading	Partner reading is a cooperative activity that encourages peer-to-peer learning. It is	Pairs	<p>Option 1</p> <ol style="list-style-type: none"> 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).

	<p>a routine for fluency practice only when students have previously read the text.</p>		<ol style="list-style-type: none"> 2. Partner B reads the same passage while Partner A listens and comments. <p>Option 2</p> <ol style="list-style-type: none"> 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.
<p>Save the Last Word</p>	<p>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.)</p>	<p>Groups</p>	<ol style="list-style-type: none"> 1. Students receive a quote, text, video clip, or other media that serves as the catalyst for this activity. 2. Students read/view the selection. 3. 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). 4. 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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