Teacher's Edition

IQWST

Earth Science

What Makes the Weather Change?

Second Edition

WHAT MAKES THE WEATHER CHANGE?

Atmospheric Processes in Weather and Climate

IQWST LEADERSHIP AND DEVELOPMENT TEAM

Joseph S. Krajcik, Ph.D., Michigan State University
Brian J. Reiser, Ph.D., Northwestern University
LeeAnn M. Sutherland, Ph.D., University of Michigan
David Fortus, Ph.D., Weizmann Institute of Science

Unit Leaders

Strand Leader: Brian J. Reiser, Ph.D., Northwestern University
Lead Developer: Lou-Ellen Finn, Northwestern University

Unit Contributors

Daniel C. Edelson, Ph.D., National Geographic
Kemi Jona, Ph.D., Northwestern University
Eunmi Lee, Ph.D., DePaul University
Michael Novak, Park View School, Morton Grove, IL
Matthew Rossi, Arizona State University
Keetra Tipton, Park View School, Morton Grove, IL
Robert Lazars, Chicago Public Schools, IL
Mary Pat Pardo, Chicago Public Schools, IL

Unit Pilot Teachers

Michael Novak, Park View School, Morton Grove, IL
Keetra Tipton, Park View School, Morton Grove, IL
Robert Lazars, Chicago Public Schools, IL

Unit Reviewers

Nir Orion, Ph.D., Weizmann Institute of Science
Project 2061, American Association for the Advancement of Science
Ann Rivet, Ph.D., Teachers College, Columbia, NY

Investigating and Questioning Our World through Science and Technology (IQWST)

WHAT MAKES THE WEATHER CHANGE?

Atmospheric Processes in Weather and Climate

EARTH SCIENCE

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About the Publisher

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ES2 CONTENTS

ART

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Lesson 1

Atlanta Surface Area Map – Courtesy WSI Corporation, *The Weather Channel*

Belem Surface Area Map – Courtesy WSI Corporation, *The Weather Channel*

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Oslo Surface Area Map – Courtesy WSI Corporation, *The Weather Channel*

Singapore Surface Area Map – Courtesy WSI Corporation, *The Weather Channel*

Ushuaia Surface Area Map – Courtesy WSI Corporation, *The Weather Channel*

10-Day Forecast: Buenos Aires, Argentina – Courtesy WSI Corporation, *The Weather Channel*

10-Day Forecast: Ushuaia, Argentina – Courtesy WSI Corporation, *The Weather Channel*

10-Day Forecast: Belem, Brazil – Courtesy WSI Corporation, *The Weather Channel*

10-DayForecast: Atlanta, Georgia – Courtesy WSI Corporation, *The Weather Channel*

10-Day Forecast: Oslo, Norway – Courtesy WSI Corporation, *The Weather Channel*

10-Day Forecast: Singapore, Singapore – Courtesy WSI Corporation, *The Weather Channel*

Buenos Aires, Argentina Weather Report – Courtesy WSI Corporation, *The Weather Channel*

Ushuaia, Argentina Weather Report – Courtesy WSI Corporation, *The Weather Channel*

Belem, Brazil Weather Report – Courtesy WSI Corporation, *The Weather Channel*

Atlanta, Georgia Weather Report – Courtesy WSI Corporation, *The Weather Channel*

Oslo, Norway Weather Report – Courtesy WSI Corporation, *The Weather Channel*

Singapore, Singapore Weather Report – Courtesy WSI Corporation, *The Weather Channel*

Lesson 5

Cloud Cover Map – Courtesy National Oceanic and Atmospheric Administration, U.S. Department of Commerce

U.S. Surface Area Map – Courtesy National Oceanic and Atmospheric Administration, U.S. Department of Commerce

Precipitation Map – Courtesy National Oceanic and Atmospheric Administration, U.S. Department of Commerce

Texas Clouds – Courtesy National Oceanic and Atmospheric Administration, U.S. Department of Commerce

New Jersey Weather Radar – National Weather Service, U.S. Department of Commerce

Texas Radar – National Weather Service, U.S. Department of Commerce

Doppler Radar – Wikipedia, *The Free Encyclopedia*

Lesson 6

Midwest Surface Map – Courtesy WSI Corporation, *The Weather Channel*

Lesson 7

January Global Map Temperatures – Courtesy University of Oregon Department of Geography

January Air Temperatures – Courtesy University of Oregon Department of Geography

IQWST OVERVIEW

IQWST is a carefully sequenced, 12-unit middle school science curriculum, developed with support from the National Science Foundation. As designed, each academic year includes four units, one in each discipline: Physics, Chemistry, Life Science, and Earth Science. IQWST's foundation is the latest research on how students learn and how they learn science in particular. At its core, IQWST engages students in scientific practices as they experience, investigate, and explain phenomena while learning core ideas of science. Rather than memorizing facts, students build understanding by connecting ideas across disciplines and across the middle grades. The following are key components of IQWST, important whether following NGSS, the Framework, or individual state standards.

Core Ideas: Focus on a limited number of core science ideas, aiming for depth of understanding rather than the superficial coverage inherent when aiming for breadth.

Scientific Practices: Engage meaningfully in science and the work of scientists through eight practices, used singly or in combination to explore and learn core ideas *in each lesson*.

Crosscutting Concepts: Thread throughout the curriculum the seven cross-disciplinary concepts, repeatedly revisited such that students construct deep understanding of the ideas as they apply to each science discipline.

Coherence: Build understanding through a progression within each grade level and across grade levels. Learning critical concepts and practices across content areas and grades provides students with opportunities to develop, reinforce, and use their understandings on an ongoing basis throughout their middle school years.

Performance Expectations: Identify *how* students engage with a specific practice in order to learn a specific core idea and to build increasing understanding of a broader crosscutting concept.

THE IQWST UNIT SEQUENCE: BUILDING COHERENCE

Although IQWST units can be enacted in a manner that meets district needs, they are designed based on research that shows the importance of coherent curriculum, structured such that students build understanding as they revisit ideas across disciplinary strands, content, and grade levels and deepen their understanding across time. The *Framework* indicates, "Standards should be organized as progressions that support students' learning over multiple grades. They should take into account how students' command of concepts, core ideas, and practices becomes more sophisticated over time with appropriate instructional experiences" (NRC 2011).

The role of coherence in materials and instruction is well documented: Most science programs (textbooks and instruction) do not support deep, integrated student learning because they lack coherence (Kesidou & Roseman, 2002; National Research Council, 2007). Yet presenting interrelated ideas and making connections between and among them explicit (Roseman, Linn, & Koppal, 2008) was found to be the strongest predictor of student outcomes in the Trends in International Mathematics and Science Study (TIMSS) (Schmidt, Wang, & McKnight, 2005).

Curricular coherence is best accomplished through teaching the ideas in IQWST units in a recommended sequence. That sequence aligns with NGSS, which treats a core idea such as "energy," for example, as both a Crosscutting Concept and a Core Idea. In IQWST, students engage with ideas about energy in the first physical science unit of the sequence and then revisit energy concepts in life science, chemistry, and Earth science—and in later physical science units—so that as students apply energy ideas to new content and contexts, their understanding of one of the most challenging concepts in science education deepens across middle school.

The following chart illustrates the recommended sequence for optimum curriculum coherence, enabling students to build on and revise their understanding of core content and to strengthen their ability to successfully engage in scientific practices over multiple years.

IQWST MIDDLE SCHOOL CURRICULUM

Level 1	Physical Science	Introduction to Chemistry	Life Science	Earth Science
	Can I Believe My Eyes? Light Waves, Their Role in Sight, and Interaction with Matter	*How Can I Smell Things from a Distance?* Particle Nature of Matter, Phase Changes	*Where Have All the Creatures Gone?* Organisms and Ecosystems	*How Does Water Shape Our World?* Water and Rock Cycles
Level 2	Introduction to Chemistry	Physical Science	Earth Science	Life Science
	How Can I Make New Stuff from Old Stuff? Chemical Reactions, Conservation of Matter	*Why Do Some Things Stop While Others Keep Going?* Transformation and Conservation of Energy	*What Makes the Weather Change?* Atmospheric Processes in Weather and Climate	*What Is Going on Inside Me?* Body Systems and Cellular Processes
Level 3	Earth Science	Life Science	Physical Science	Introduction to Chemistry
	How Is the Earth Changing? Geological Processes, Plate Tectonics	*Why Do Organisms Look the Way They Do?* Heredity and Natural Selection	*How Will It Move?* Force and Motion	*How Does Food Provide My Body with Energy?* Chemical Reactions in Living Things

UNIT STRUCTURE

Driving Questions

Each IQWST unit focuses on a Driving Question, which is also the unit's title. A Driving Question is a rich, open-ended question that uses everyday language to situate science content in contexts that are meaningful to middle school students. As each unit progresses, the phenomena, investigations, discussions, readings, and writing activities support students in learning content that moves them closer to being able to answer the Driving Question in a grade-appropriate manner.

Learning Sets

IQWST lessons are grouped into three to five learning sets per unit, each guided by a subquestion that addresses content essential to answer the Driving Question. This structure unifies lessons and enables students to meet larger learning goals by first addressing constituent pieces of which they are comprised.

IQWST lessons support research-based instructional routines with several components designed and structured to meet teacher needs. Each lesson comprises multiple activities (i.e., Activity 1.1, Activity 1.2) that altogether address one to four Performance Expectations (as described in NGSS). Each lesson is preceded by lesson preparation pages, Preparing the Lesson, as described in the following Lesson Structure section.

LESSON STRUCTURE

Each IQWST lesson contains common components to support teachers as they progress through the unit's activities.

Preparing the Lesson

The information on the first pages of each lesson supports the teacher in previewing and preparing for the lesson.

Teacher Background Knowledge

This section describes content to be addressed in the lesson, specifics about use of language or measurement tools, and prerequisite knowledge students are expected to have. If IQWST units are taught in the designed sequence, prerequisite knowledge is that which is expected from elementary school. If IQWST units are taught in an alternative sequence, this section alerts teachers about what students will need to understand in order to make sense of activities in a unit and to achieve its learning goals. This section also addresses content that may lie outside of teacher expertise in order to support teachers in working with content with which they are less familiar.

Sometimes, a Common Student Ideas heading describes ideas from research on misconceptions or describes other difficulties students have been shown to have with the content of a particular lesson. The section may describe prior knowledge that does not align with accepted science and that may be a stumbling block to understanding.

Setup

Setup is noted on the preparation page when the teacher needs to prepare materials ahead of time, such as mixing solutions, premeasuring materials for student groups, or setting up stations.

Safety Guidelines

A section on safety is included in the IQWST Overview. Within units, safety guidelines specific to a lesson are sometimes described separately so as to call attention to them. Examples include how chemicals should be handled and disposed of or when wafting is necessary rather than inhaling substances.

Differentiation Opportunities

Differentiation ideas highlighted prior to a lesson specify ways to either go beyond the performance expectations for the lesson or to support students who need additional help with content. Differentiation strategies that can be applied across lessons are described elsewhere in this Overview.

Building Coherence

This section briefly situates the lesson in those that precede and follow it and often references content students will have encountered in previous IQWST units, if units have been enacted in the recommended sequence.

Timeframe (Pacing)

This note estimates the number of class periods the lesson will take to complete based on widespread classroom experience. Richer discussions, more time spent on reading or writing skills, enacting demonstrations as group activities or vice versa, and other teacher-chosen adaptations require adjusting the timeframe. Most lessons require two or more class periods, as most are composed of multiple activities. Pacing is based on 50-minute class periods. Longer or shorter periods, or block schedules, require adjustment so that each class session is a coherent whole. Suggested pacing is also noted on the Unit Calendar located in the front matter.

Overview

A succinct list provides a snapshot of primary activities within a lesson, identified by activity number (i.e., Activity 1.1, Activity 1.2).

Performance Expectations

Performance Expectations describe what students should *know* and *be able to do* in a given lesson. Performance expectations describe one or more scientific practices in which students will engage in order to learn a disciplinary core idea, often also addressing a crosscutting concept, such that teachers can effectively plan, focus, and assess students' understanding.

Materials

These sections list the supplies required to carry out each activity within a lesson. They are quantified and grouped based on teacher needs, group needs, and individual needs.

Introducing the Lesson

This feature is included when activities are specifically designed to launch a lesson, often including integration of the previous reading or homework assignment.

Discussion Types

Types of discussion are described elsewhere in this Overview and are identified within each activity: Brainstorming, Synthesizing, or Pressing for Understanding. Each discussion has a stated purpose, followed by suggested prompts to guide conversation. Prompts are not intended as a script but provide teachers with alternatives they can use or from which they can shape their own questions—both factual/close ended and open ended to encourage thinking, challenging, explaining, and arguing from evidence.

Reading Follow Up and Introducing Reading

Suggestions for introducing and following up reading aid comprehension, retention, and integration of reading into science lessons. Readings are designed to be done independently, as homework, providing students with opportunities to revisit class activities, to connect science to their everyday lives, to deepen their understanding of content, and to apply their understanding to new examples and contexts. The pacing of lessons, as described, presumes that reading is not an in-class activity but is an at-home activity to extend student learning. Reading is addressed more fully elsewhere in this Overview.

Teacher Supports

Icons

Apple – Signals an "aside" to the teacher, often a strategy or a hint about student thinking likely to arise during an activity. Strategies and hints are embedded at points in the lessons that are most helpful to the teacher.

Checkmark – Signals a point at which the teacher should stop and check students' understanding before moving forward in the lesson or unit. Often, the ideas accompanied by this icon can be used as assessment opportunities.

Open Book – Signals either a reading assignment or a follow-up homework activity at the point in a lesson that it is best assigned. Typically the book icon is at the end of an activity and indicates work that is to be done in preparation for the activity that follows.

Safety – Signals precautions important to ensure safety in a lesson. Many lessons do not have specific safety precautions; instead, the lesson directs the teacher to the Overview, where general precautions, to be followed across IQWST lessons, are outlined.

Key – Signals smaller-scale learning goals that may be components of a larger disciplinary core idea. Key ideas might also include scientific principles derived from class activities, important definitions, or a new type of X to be added to a list of "types of X" students have been compiling in the unit. Key ideas might include main ideas at which students should arrive after an activity, reading, or class discussion.

Probe – Signals that technology is used in a particular lesson either for modeling (e.g., a computer simulation) or for quantitative measurement (e.g., probes and data loggers).

Pencil (only in Student Edition) – Signals places in which a written response is expected. Because questions are used as headers and are also woven throughout readings to engage students as active readers, an icon is used to indicate when a written response, rather than simply "thinking about," is required.

Projected Images (PI)

The value for students of seeing images in science cannot be overestimated. Projected Images (PI) are to be displayed for the class. Selected images may be printed for display on the Driving Question Board and perhaps laminated for reuse.

Each IQWST lesson includes projected images, charts, and graphs to expand students' understanding of science concepts. These colorful images are most effective for instruction if they are displayed in the front of the room on the white board. The images are located on the IQWST Portal in each unit folder, and all are named clearly.

The IQWST Portal

The IQWST Portal is an online resource for educators and students to access IQWST curriculum resources, including teacher editions of IQWST textbooks, student lab books, unit materials lists, assessments, and more. The IQWST Portal also provides access to digital resources including lesson-specific videos and audio files with narration of every student reading. Interactive resources and simulations like NetLogo are also located on the IQWST Portal.

The IQWST Portal is organized with each of the 12 units listed as a course. Within each course the content is divided into learning sets that are composed of multiple lessons. Within the lessons, educators can access digital versions of IQWST print materials, digital resources, and interactive resources. Each unit also contains a news section with up-to-date links to articles and research relevant to physical science, chemistry, life science, and Earth science.

DIFFERENTIATION IN IQWST

Range of Student Learners

Strategies built into IQWST lessons acknowledge students' differing capabilities, expectations, experiences, preferred learning styles, language proficiency, reading strategy use, and science background knowledge, among others. Materials address diverse needs by connecting classroom science to students' everyday, real-world interests and experiences. Each activity provides opportunities for teacher guidance, for independent work as well as small-group and whole-group interaction, for investigation, for discussion, and for reading, writing, and talking science. Opportunities for differentiation abound in each of these areas and in each lesson, so all students can work at their appropriate level of challenge.

Activity-based experiences enable students to share common experiences from which to build understanding. Students with kinesthetic preferences can use their strengths as doers and problem solvers. Those with verbal preferences can talk and write about processes and practices and can contribute ideas from readings to the discussion. Those with tactile preferences can manipulate materials. Those with visual preferences observe rather than only read about science. IQWST does not require memorizing definitions, writing paragraphs using vocabulary, or writing lab reports. Students with a range of learning preferences, language abilities, and other strengths and weak areas as learners can contribute to, engage in, and learn from each investigation—independently and collaboratively.

Specific differentiation opportunities are described in the Preparing the Lesson pages that precede each lesson. The following general strategies apply across IQWST.

General Differentiation Strategies

- Students begin each unit with an activity to generate original questions that will form the Driving Question Board (DQB) for the unit. Some of their questions will not fit into any of the categories used to organize the DQB and will not be addressed in the unit. Such questions may be assigned to students as an ongoing, individual project that they complete using various resources.
    - Such projects enable students who benefit from "going beyond" the unit to do so independently. With the teacher's discretion, projects for advanced students might come from such work, requiring use of multiple resources with varied text complexity.
    - Passionate interest has been shown to motivate students who struggle with reading to nonetheless read texts well beyond their Lexile level or presumed "ability" in a quest to learn more about something they are invested in. English Learners, students with learning disabilities, and struggling readers should thus be encouraged to investigate topics in which they are keenly interested. Some students will need support with resources (e.g., Internet search terms or suggested websites), but it is important to encourage all students to pursue areas of interest.

- Two follow-up questions that students cannot get wrong, simply by virtue of having read are (1) What did you find most interesting about last night's reading? and (2) What is one new thing you learned as you read last night's assignment? Some variation of either of these questions can be used for accountability purposes (i.e., Did the student read?) and for encouragement purposes (i.e., There are no wrong answers).

- Discussion is important to allow exchange of ideas and examination of one's own ideas. Many students, especially English-language learners, students with learning disabilities, or students with auditory processing difficulties, struggle to make sense of a question and formulate a response in time to raise their hands and articulate their ideas orally. For such students, consider a think-pair-share strategy. Pose a question and provide students with time to *think* about their response (or to write their ideas). Then, *pair* students with partners to *share* ideas. The teacher can then call on a pair, who can give a response they have had time to rehearse. This activity can be taken a step further to *square* the response by having two pairs talk together.

- Some students participate more fluently and comfortably if they are sometimes told ahead of time which question they are going to be asked to share their ideas about. Preparation time allows them to jot notes, to practice orally, or to reread a written response and be confident about sharing aloud. A teacher can prepare a sticky note such as "Be ready to talk about your answer to Question 3," and can place that note on a student's book in the course of teaching a lesson. This enables students with a range of language proficiencies, background knowledge, memory, or ability to process information time to think through their ideas and thus to be more confident and successful sharing in whole-class contexts.

Reading Differentiation Strategies

- Readings are designed based on research indicating that when students are passionate about a topic they often read well beyond their determined "reading level." Thus, IQWST readings emphasize engaging students in science. In many programs, reading level is simplified by shortening sentences and using easier vocabulary. However, doing so shortchanges students in two ways. First, shorter sentences require removal of connecting words (therefore, so, then) that actually support comprehension. Second, simplifying text by limiting multisyllabic words shortchanges students by ensuring that weaker readers remain unable to engage with texts that use the vocabulary of science. Therefore, IQWST does not differentiate with simplified materials but with strategies that support readers to learn all they can from the texts provided.

- IQWST lessons provide strategies for introducing reading, monitoring student comprehension, and following up on reading assignments. A Getting Ready section begins each reading as a research-based strategy for improving comprehension—the sections generate interest and engage students, activate prior knowledge, and provide a purpose for reading. Although these strategies support all students, struggling readers can be explicitly taught the value of each of these components as strategies successful readers use to improve comprehension. Strong readers, often unknowingly, "wonder" about what they are about to read, thus providing a purpose for reading that improves their comprehension and retention.

- Reading in science contains both main ideas and important details. Some IQWST readings employ methods for students who need to continue to work on reading strategies with built-in prereading strategies and advance organizers to help students with both text structure and content. Teachers may create additional advance organizers, as desired for particular readings.

- Encourage students to read all of the written material, as it is designed to support learning of key concepts, and to extend the application of key ideas into the real world thus to generate interest in science. However, many options enable the teacher to support struggling readers, students with learning disabilities, English Language Learners, and advanced students.

    - If students find an assignment overwhelming, let them know what to focus on as they read, perhaps indicating (or marking) two or three sections of the reading that they should read carefully. Doing so gives them freedom to read all of the material but focuses their reading so that they are more likely to experience success when they can participate in follow-up class discussion because they focused on the "right" section of the reading.
    - When a reading has multiple examples (e.g., a reading about how the eyes of three types of animals work), invite students to prepare to talk about any one of the three. Doing so does not erase the opportunity to read all but enables students to make choices and to focus their reading, providing encouragement and small steps toward success.
    - Many opportunities exist for advanced students to conduct Internet searches and read more complex texts as they either pursue areas of interest or are assigned such work by the teacher.

- Support readers by pre-identifying challenging language in the readings. On the board, write 2-3 words likely to be stumbling blocks, pronounce them, and provide connections (if possible) to everyday use of such words or to cognates for English-language learners (e.g., consulting an English/Spanish science glossary). IQWST is built on a strong research base showing that the best way to learn vocabulary is to encounter and use words in context. Use an interactive Word Wall to display words so that they may be referred to often. Pre-identifying and pronouncing words that might cause difficulty is not meant as a strategy for teaching vocabulary but only as a way to ensure that when students encounter Leonardo da Vinci's name or see "optical illusion" in print, they will not experience unfamiliar words as roadblocks.

- Readings should be previewed and followed up in class, and soon most students, even struggling readers, will attempt at least portions of the reading. Even if they do not read the entire assignment, or do not read well, students will make sense of whatever they do accomplish in ways that will help them learn. IQWST is not a textbook-driven curriculum, so using class time to read the materials does not align with a project- and inquiry-based philosophy in which students experience phenomena and then think about, write about, talk about, and read about science to learn content in meaningful ways. Encourage reluctant readers by asking follow-up questions that draw on examples from the reading, making the focus not on details, but on sense making, so that all can feel successful and encouraged to read.

Writing Differentiation Strategies

- Writing in science must be clear and accurate. For students with motor skills difficulties, provide ample writing space by using the margins, the back of the page in the student book, or additional paper. Students can also write on a computer, print, and paste the page into the student book.

- To support students with learning disabilities, who may omit words in writing, suggest that they read their own writing aloud, as they can often "hear" omissions when they do so. Alternatively, a peer or family member can read a written response aloud to allow students to self-correct as they hear errors in their writing. Another person may also scribe while students who struggle with writing provide oral responses, allowing students to express their understanding of science ideas and to communicate more successfully.

Mathematics Differentiation Strategies

- Measurements in science are precise, and measuring using science equipment can be difficult. Collaborative investigations enable students with varied strengths to work together. Although all students should learn how to use the tools of science, students who have difficulties with motor skills or vision impairments, for example, do not need to physically measure or be the person solely responsible for reading the thermometer. Instead, students work together to carry out investigations.

- Procedures in science require a sequencing of steps that can be difficult for some students if instructions are given only orally or only in print. To support all students, review written instructions orally, step-by-step, as needed. Have students reread procedures even after they have been reviewed. Demonstrate procedures for investigations that are anticipated to cause confusion or frustration. Many students are more successful if they check off steps as each is completed.

SCIENTIFIC AND ENGINEERING PRACTICES

The *Framework* and NGSS identify eight practices that build and refine scientific knowledge and thus are central to the scientific enterprise. Rather than separate content knowledge and inquiry skills, as in previous versions of national standards newer standards move toward combining core content and scientific practices in tandem. IQWST is based on the same extensive research that forms the foundation of science education for the 21st century and the basis for the *Framework* and NGSS. Thus, IQWST lessons integrate and continually reinforce practices such that students develop greater facility with and deeper understanding of these practices and of the content they address, whether NGSS, the Framework, or state standards guide learning.

Engaging in scientific practices enables students to experience how it is that scientists come to particular understandings rather than to experience science as a set of complete, discrete, isolated facts. In addition, a focus on practices, as an extension of previous approaches to inquiry, expands students' understanding of science beyond viewing it as a limited set of procedures or as a single approach typically characterized as "the scientific method."

Scientific practices require both knowledge and skill, and IQWST approaches scientific practices in that manner; they are always contextualized. Rather than a lesson about "how to construct a good scientific explanation," explanations are taught in the context of a lesson about core content using the construction of an evidence-based explanation as a way to think about, make sense of, and communicate one's understanding of phenomena. All eight practices are reflected throughout IQWST. However, each unit's learning goals emphasize particular practices, emphasizing those best taught (and practiced) in the context of a given unit's learning goals and investigative activities.

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics, Information and Computer Technology, and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Each of these is addressed individually in sections that follow.

Scientific Practice 1: Asking Questions and Defining Problems

A key IQWST instructional component is each unit's Driving Question. A driving question is a rich, open-ended question that uses everyday language to situate scientific principles in contexts that are meaningful to middle school students. The discussions, investigations, science readings, and writing activities all relate to the Driving Question. IQWST involves students in constructing, evaluating, communicating, and reaching consensus on scientific explanations of how and why phenomena happen. In order to engage in this practice, students must make sense of phenomena they study and then articulate and defend their understandings to themselves, each other, the teacher, and other audiences. As each unit progresses, students learn content that moves them closer to being able to answer the Driving Question in a grade-appropriate manner. As important, each unit purposefully solicits students' original questions and provides the teacher with guidance about posting those questions on a Driving Question Board in the classroom and integrates them into the lessons. Thus science becomes "what I wonder about" rather than only "what I am told I should think about."

In addition, in the process of exploring phenomena and wondering how and why things happen, students question one another about what they observe and the conclusions they draw. They question one another about the texts they read. They learn about questioning in this manner, as well as asking testable questions that students can answer by designing, planning, and carrying out an investigation. In some IQWST units, students work together to define a problem, determine how to find a solution, and compare ideas with others in the process of solving the problem.

Driving Question Board

To organize each IQWST unit, the Driving Question is displayed on a Driving Question Board (a bulletin board or large area on a wall). The Driving Question Board (DQB) is a tool used throughout IQWST to focus students' attention, record what they have learned, and show students where they have been and the direction they are going. The DQB serves as a visual reference that remains in place throughout a unit. Lesson plans typically guide the teacher in their use. Although the teacher maintains the DQB, because it functions as a shared space to represent learning, students might also contribute regularly to the display.

Each IQWST lesson addresses a component of the unit's Driving Question, supporting students in making sense of science content and determining which part of a question they can answer and which they still need to investigate. Thus, new lessons are motivated, in part, by what questions still need to be addressed. The visual display supports teachers and students in tracking and organizing ideas along the way.

Each unit invites students to post their own original questions on the DQB to encourage active engagement in a participatory classroom culture. As they think of new questions at any time during the unit, students write those questions on sticky notes and add them to the class DQB. Across a unit, the Driving Question Board will come to include the unit-specified question and subquestions, as well as student questions, drawings, photographs, artifacts, objects, and sample student work. The DQB will serve as a focal reference helpful to all but especially important for students for whom visual representations aid in their learning, such as connecting new ideas to previous understandings. Revisit the DQB with students in each lesson. Refer to it often. Point to artifacts displayed on it as a reminder of previous activities or understandings. Post on it summaries of scientific principles, as well as artifacts students create that relate to specific questions. Any projected image used in IQWST could be printed, laminated, or inserted into a plastic sleeve and displayed on the Driving Question Board. This includes models or data tables developed as a class or any other visual representation of concepts students have studied.

Space on the Driving Question Board may be limited, but it is important that aesthetics and the neatness of the DQB do not outweigh the support provided to students when they can frequently refer to the visual representations as a reminder of activities done and content learned throughout a unit.

Scientific Practice 2: Developing and Using Models

The *Framework* describes the central role of constructing and using models to explain: "Science often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observations and imagine a world not yet seen. Models enable predictions . . . to be made in order to test hypothetical explanations." NGSS specifies that models can include "diagrams, physical replicas, mathematical representations, analogies, and computer simulations," all of which contain "approximations and assumptions" that students need to learn to recognize as a given model's limitations. In science, models are used to help people understand, describe, predict, and explain phenomena in the real world.

Scientific modeling consists of several core practices: constructing models, using models to explain or predict, evaluating models, and revising models. IQWST engages students in all of these, supporting learners as they develop models, use models to explain, use models to predict, critique one another's models, and revise models as they learn new information—engaging in modeling as real scientists do. Because modeling is often connected with other aspects of scientific practice, students' experiences with modeling are embedded in the broader context of investigating, understanding, and explaining phenomena. Students create and use models to understand and apply scientific ideas, to illustrate and defend ideas, and to evaluate interpretations.

Engaging Students in Modeling

Students need to understand the purpose of models and modeling in science in order to effectively engage in the practice of developing and using models. Initially, it may be useful to have students think about other models they know, such as models of weather phenomena that scientists use to explain and predict the path of hurricanes, tornadoes, thunderstorms, or snowstorms.

Before Students Develop Models

1. It is helpful to emphasize that the point of developing models is to try to explain the phenomenon just investigated in class. Students' models should demonstrate their best ideas about how to show how and why X happened, so that the model can be used to explain what happened to someone else.

2. Begin to develop criteria for good models, which can be posted in the classroom and used throughout IQWST as students develop their own models and critique one another's models. These ideas should come from class discussion and should be written in students' own language. Important ideas include the following:
   a. Models need to explain. Does the model show *how* and *why* the phenomena happened the way they did? Is there anything in the model that does not need to be here? Are there steps we are leaving out?
   b. Models need to fit the evidence. Does this model fit what was seen about the phenomenon?
   c. Models need to help others understand a phenomenon. Is the model easy to understand? Are there ways to clarify what it shows?
   d. As lessons lead to the need for model revision to account for a new phenomenon, address the idea that models also can be used to predict. Probe students with the following questions: What does our model predict about what will happen in situation X? Was that what actually happened? What does that mean about our model? What do we need to revise based on our new evidence?

Before Students Share Models

It is helpful to give students guidance about how they should listen to each other as they present their models. Eventually students will ask critical questions and make constructive suggestions to each other. Be sure to support that process until they understand this kind of classroom discourse. The following are ideas to address:

1. Different ideas will arise as we try to figure things out. This is our chance to put our heads together and come up with the best model we can come up with, as a group. But we need to agree on what we are looking for. As we listen to each other explain our models, remember what we created these models to try to do. Let's talk about what is important.
2. All scientific models have limitations. Not every aspect of a phenomenon can be explained using a single model. Models often simplify as they illustrate things that are too small, too large, too fast, or too slow to observe without a model as a representation. A static model cannot show movement. No model can sufficiently illustrate the number of molecules involved in a phenomenon nor the time required for others to take place.
3. More than one model can be used to explain the same phenomenon. Scientists judge how good a model is based on how well it helps to explain or predict phenomena—not by how similar it looks to the thing it aims to explain or describe. For example, a good model of gases can be used to explain all the behaviors of gases observed in the real world (e.g., what happens when air is cooled, heated, or compressed), but it will not be used to explain the behavior of solids. Different models have different advantages and disadvantages.

Constructing Models Depends on Scientific Argumentation

The practice of constructing models in IQWST draws critically on another scientific practice, Engaging in Argument from Evidence. In the practice of constructing models in IQWST, argumentation occurs when students defend their proposed models, showing how the model fits evidence and explains the phenomena. Argumentation occurs in classroom discourse when comparing and discussing competing models. IQWST lessons contain support for students to critique one another's models and ultimately to reach consensus, both critical parts of the argumentation practice.

Scientific Practice 3: Planning and Carrying Out Investigations

IQWST is an activity-based, phenomena-rich, investigative curriculum. Students plan investigations that address the Driving Question for each unit and carry out investigations in each lesson. The investigations build understanding of core ideas throughout each unit, always directed at gaining more understanding toward being able to answer the Driving Question. In addition, students' original questions not answered in the unit can be used as a springboard for additional investigation. Some investigations arise out of previous ones in a process of figuring out "what we know as a class" and "what we need to figure out next," typically in learning the how and why of a process. Any such questions can motivate further investigation. Thus, besides those opportunities provided by the curriculum itself, the teacher can require or encourage the planning and carrying out of investigations that extend student learning beyond the performance expectations of a given unit.

Carrying out a multistep procedure is an important science literacy skill; thus teachers might have students plan investigations, write procedures, and share plans and procedures with other groups to read and critique.

Scientific Practice 4: Analyzing and Interpreting Data

IQWST units engage students in observation, data collection and organization, interpretation, and using data to make sense of phenomena they investigate. All lessons regularly use the language of "observation," "data," and "evidence." Teachers are encouraged to ask students to support their ideas with evidence (e.g., Why do you think that? How could that happen? What if . . . ? What evidence do you/we have for that?), requiring students to consider their data carefully. Teachers encourage students to question data provided by others. This creates a situation in which using data as evidence to defend a claim makes sense—students need evidence because they will be questioned about their data in discussion.

Students analyze both qualitative and quantitative data in IQWST. They learn that both are important and while observation with the unaided eye enables them to make some significant claims, instrumentation and scientific tools enable them to be much more precise. Students analyze data they have collected themselves as well as data collected by others (e.g., changes in a population over time, melting points of substances they are unable to investigate in the classroom). Charts and graphs require understanding of independent and dependent variables, and investigations require understanding of what it means to control variables. Throughout the units, IQWST provides students with multiple opportunities to analyze and interpret data through classroom discourse as a whole class, in small groups, in pairs, and independently, providing practice in multiple contexts that reinforce the development of this scientific practice.

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Scientific Practice 5: Using Mathematics, Information and Technology, and Computational Thinking

NGSS specifies within this practice ideas such as "using digital tools," for example, "to analyze very large data sets for patterns and trends" and "to test and compare solutions to an engineering design problem." In addition, this practice specifies a need for students to "measure and compare quantitative attributes of different objects and display the data using simple graphs." Therefore, IQWST units include lessons that include probes, sensors, data loggers, and a sensor interface as digital tools that enable quantitative measurement and graphic display in a manner in which real scientists do their work.

IQWST uses the language of *probes*, *sensors*, *data loggers,* and *sensor interface* for illustrative purposes, given rapid changes and advancements in technology and the attempt to use generic terms where possible. IQWST materials show photographs of and reference Pasco brand probes for several activities, as Pasco makes high-quality equipment for middle school use. If your school uses another brand of technology, adjustments may be required in the instructions to students. If your school does not have probeware, and you elect not to purchase such equipment, then more significant adjustment to activities will be necessary, especially where measurements may not be made quantitatively without similar devices. It is recommended, in keeping with the NGSS call for the types of scientific practices considered integral to science education, that probeware be used as recommended in IQWST. More specific guidelines and instructions specific to brands of probeware may be found on the Teacher Portal with updates available to teachers in a timely manner.

Mathematics is used throughout the IQWST program as students take measurements using the tools of science, collect data, plot data on graphs or create data tables, and come to understand and work with dependent and independent variables. Students use scientific probes to calculate in the manner of scientists. Computers are used for simulations of models of phenomena, such as predator/prey relationships, or for observing a phenomenon in slow motion so that it can be more carefully examined.

Scientific Practice 6: Constructing Explanations and Designing Solutions

The *Framework* defines explanations as "accounts that link scientific theory with scientific observations or phenomena" and identifies the related engineering practice of designing solutions, in which students construct and defend solutions to problems that draw on scientific ideas. In IQWST, these two aspects of the practice are combined as constructing, evaluating, and defending evidence-based scientific explanations. The scientific practice of explanation goes beyond asking students to describe what they know about a particular idea. Instead, students develop a chain of reasoning that shows why the phenomenon occurs as it does.

For example, rather than asking students simply to "explain the process of cellular respiration," an IQWST Life Science Unit asks students to "explain why the air a human breathes out contains less oxygen than the air breathed in." Students not only describe the process of respiration but also construct a causal chain that fits the evidence. Drawing on prior ideas from chemistry and physical science, such a chain should specify where glucose goes in the body, what materials can get into and out of cells, and conclude that a chemical reaction requiring both glucose and oxygen must be taking place in cells to convert energy to a form the organism can use.

What Does It Mean to Construct an Explanation?

In the practice of constructing explanations in IQWST, students make claims, use data as evidence to support their claims, and engage in reasoning that draws on scientific principles, or the "what we know" in science, to explain the "how" and "why" of phenomena they investigate in the classroom. Teachers pose questions that push students to think more deeply about what they have observed, read, and experienced, modeling this practice so that students learn to question one another. IQWST lessons support students in critiquing one another's explanations, providing students with opportunities to talk, to write, to discuss, to give and receive feedback, and to revise the explanations they have constructed. Many literacy standards are addressed as students cite evidence from sources; integrate information from observations and from text; write arguments that use a claim, use data as evidence, and use logical reasoning in an explanatory text; and engage in revision focused on writing clearly and coherently for a specific purpose and audience.

Supports are designed around a framework that divides scientific explanations into three smaller, manageable, and teachable components for middle school students: claim, evidence, and reasoning (referred to as the C,E,R framework). IQWST identifies these components in order to support students as they learn to write in a new way.

Claim

A claim is a statement of one's understanding about a phenomenon or about the results of an investigation. The claim is a testable statement about what happened. The claim expresses what the author is trying to help the audience understand and believe.

Claims may be made about data that students have been given or they have gathered themselves. If an investigation has independent and dependent variables, the claim describes the relationship between them.

In practice, teachers have found it useful to teach that a claim must be a complete sentence, cannot begin with "yes" or "no," and is typically the first sentence of an explanation. Although it is not necessary that a claim be the first sentence, experience has shown that freedom to vary the guidelines is best managed *after* the guidelines and their purpose have been learned.

The claim is often the part of an explanation that students find easiest to include and to identify as they critique others' explanations. One of the purposes of focusing on evidence-based scientific explanations is to help students include more than a claim (or "simple" answer to a question) in their writing.

Evidence

The evidence consists of the data used to support the claim. The evidence tells the audience the support the author has collected that makes the claim convincing.

An explanation must contain accurate and sufficient evidence in support of the claim. Evidence makes claims understandable and convincing. While "data" can refer to all the observations that students have collected or analyzed, data become "evidence" when used to support a claim. The evidence for explanations can come from investigations students conduct, from observations they make, or from reports of empirical research others have done. Where possible, explanations incorporate more than one piece of data as evidence.

A goal in IQWST is to help students understand that data must be marshaled as evidence in support of a particular claim. In complex situations, more than one claim might be made about a single data set. It might also be that more data are available than are necessary to support a particular claim. Students must determine which are the appropriate data to use in support of a claim they have made and what are sufficient data to support that claim. The idea that multiple claims might be made using the same data develops across the curriculum as the inquiry activities become more complex, and students' options for research questions (and resulting claims and evidence) become increasingly open ended.

Reasoning

Students learn that the accepted scientific understanding or principles that underlie the explanation must be made explicit in a process IQWST calls reasoning. The reasoning presents the logic that leads from the evidence to the claim and, if possible, connects it with a scientific principle. The reasoning says why the claim makes sense, given what is understood so far about the phenomena. Reasoning ties in the scientific knowledge or theory that justifies the claim and helps determine the appropriate evidence. The reasoning may include a scientific principle that reflects the consensus students have developed so far about the phenomena they are investigating. It may also require a logical chain that shows how the principle and evidence work together to support the claim. For example, the reasoning for the effects of a competitor X on population Y may refer to a series of connected steps that start with the increase in population size of the competing species X, decrease of available food sources needed by both X and Y, and then drop in population size of Y due to lack of food.

The reasoning connects to the general knowledge of the scientific community and a chain of logic to explain how particular data support a claim, given what scientists know about the world. Reasoning is the most difficult aspect of explanation writing for students to understand and is the most difficult aspect for teachers to teach. Reasoning requires relating general scientific principles—what is already known in science—to the specific question being investigated and requires students to make explicit the steps of their thinking.

Scientific Practice 7: Engaging in Argument from Evidence

The *Framework* defines the central role of scientific argumentation in building scientific knowledge as "a process of reasoning that requires a scientist to make a justified claim about the world. In response, other scientists attempt to identify the claim's weaknesses and limitations." In the practice of constructing explanations in IQWST, argumentation occurs when students defend their explanations both in written form, by providing supporting evidence and reasoning, and in classroom discourse, when comparing and discussing competing explanations. IQWST lessons contain support for students to critique one another's explanations and to reach consensus, both critical parts of argumentation. Students learn about criteria for critiquing explanations that also apply to arguments: both must fit the evidence, be logically coherent, fit what is known in science, and include important steps in reasoning.

Argumentation is key in IQWST thus significant attention is paid to evidence-based explanation and argumentation, and students engage in this practice in every IQWST unit.

Scientific Practice 8: Obtaining, Evaluating, and Communicating Information

Student readings provide additional information to support students' in-class investigations. Readings are designed to be integrated into each lesson such that students obtain, evaluate, and communicate information from multiple sources—their own work, others' work, and the science they read about—in all that they do. In addition, opportunities abound for additional research using the Internet, for example, so that students can pursue areas of individual interest that go beyond the performance expectations and grade-level standards. That is, a student who reads about solar sails, described in an IQWST reading as an example of the use of solar power, might wish to learn more about what solar sails are and how they work. Such reading might also trigger interest in alternative forms of energy and their advantages and disadvantages and lead to a written project as situated in the context of the science being studied. This can enable a student to apply his or her understanding to global concerns or to issues in the local community. Such projects, models, and written products that result can interest and motivate students, deepen content understanding, encourage engagement in scientific practices and literacy practices related to science, and provide application and extension opportunities beyond the classroom. In addition, deeper understanding will likely be fostered as the student encounters new ideas in science that fit with the knowledge gleaned from such a project as the core of learning—connecting new understandings with prior knowledge—is strengthened. IQWST does not require research paper types of projects; however, opportunities for teachers to collaborate across content areas such that students might explore science topics as a way to meet literacy learning goals is an option, given that students are likely to encounter many topics they wish to explore further as they investigate phenomenon and read, write, and talk science in every lesson.

INSTRUCTIONAL SUPPORT FOR SCIENTIFIC PRACTICES

The following strategies support students in developing experience with scientific practices.

Use Data to Build Understanding

As designed, earlier IQWST units help students become familiar with observation and data collection and with using data to make sense of phenomena. Teachers are encouraged to ask students to support ideas with evidence (e.g., Why do you think that? How could that happen? What if . . . ? What evidence do you/we have for that?). Teachers allow students to question evidence provided by others. This creates a situation in which using data as evidence to defend a claim makes sense—students need evidence because they will be questioned about it in discussion.

Model the Practice

The teacher uses a think-aloud process to make thinking visible to students. This highlights the underlying aspects of scientific practices, making them explicit as the teacher "talks through" his or her thinking, modeling how good writers, modelers, thinkers, observers, or questioners think as they engage in the practice.

Identify the Audience

All written tasks should be constructed with an audience in mind. This helps students shape their writing, so that the audience can make sense of a written explanation, a model, or a representation of data. In IQWST, students may be asked to think about convincing someone from another class of the validity of the claim in an explanation, to share with someone at home and get feedback, or to explain to an absentee student, someone new the school, or an elementary student.

Motivate the Practice

As teachers incorporate explanation construction and modeling into lessons, they must help students move back and forth between the components of the practice (e.g., claim, evidence, reasoning) and the overall purpose of the practice. Otherwise, focusing on the components becomes formulaic, and students lose sight of the purpose of explanations and modeling in science. To help students see a need for this work, they are placed in situations in which they must engage in argumentation as a way to "convince" someone that their conclusions make sense and can be supported with data.

Generate Criteria

When students are asked to convince one another and to determine whether they are convinced by someone's claim, they need criteria on which to base decisions. Although teachers begin with criteria in mind (described in each unit), they guide students to develop criteria in their own words. The framework can be given to students at the outset; however, students have a deeper understanding of the components and more buy-in when they work cooperatively as a class to generate criteria or the framework for an explanation.

Critique Examples

Students are accustomed to process writing in ELA, but they tend to think that once something is written in other content areas it is finished. Whole-class, teacher-led, and small-group critique of explanations and models helps students see that explanations can be revisited, rethought, and revised. A teacher can create sample explanations for critique purposes. Once students have written explanations, their work can be used anonymously for whole-class critique. Teacher-guided critique, in which the teacher asks probing questions in a discussion, is a useful next step. Once students have practiced in teacher-led sessions, they are ready to critique one another's work. In any critique, strengths and weaknesses should be highlighted and suggestions for improvement offered. It is small-group or paired sharing, in which students compare ideas and justify their use of evidence, that IQWST emphasizes. It is in those comparison and justification activities that deep conceptual understanding takes place, and it is these activities that motivate the use of explanations and models in science.

LITERACY IN THE IQWST CLASSROOM

IQWST supports literacy for diverse learners as students transition from *learning to read and write* in elementary school to *reading and writing to learn* in middle school. Lessons draw on the most recent research in literacy learning, with emphasis on reading comprehension and on the role that reading and writing—in tandem—play in learning. In IQWST, students learn by engaging with the tools, materials, ideas, and principles of science and by thinking, reading, writing, and talking science.

Literacy practices are integrated into every IQWST lesson. The curriculum encourages students to be reflective and critical thinkers, to ask questions of the teacher and each other, to share in small- and whole-group discussion, to read texts that connect science to their everyday lives and prior knowledge, to write responses to embedded questions, to construct models and written explanations and to revise them, to engage in argumentation to defend their ideas and to challenge one another's thinking.

Student books are consumable, functioning as portfolios; the lab activity pages, models and diagrams students draw, readings, and all writing are in one place. Books can be used to teach additional skills by a specialist, support person, or teacher who chooses to teach annotation or highlighting, for example, as students write directly in their books.

Reading in Science

IQWST materials are designed to meet expectations for reading and include strategies to guide teachers in addressing literacy requirements with additional depth or to differentiate for diverse students.

LITERACY GOALS	AS ADDRESSED IN IQWST
Cite specific textual evidence to support analysis of science and technical texts.	Discussion prompts and strategies for teachers and responses to questions embedded in readings ask students to refer to text for evidence.
Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.	Summarizing or referencing central ideas from text in discussion is often done in the "Reading Follow Up" section that begins most lessons.
Follow precisely a multistep procedure when carrying out an experiment taking measurements or performing technical tasks.	Activity sheets that accompany investigations and homework activities provide extensive practice in reading and following procedures.
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to Grades 6–8 texts and topics.	The language of science is key to science learning. Thus readings address vocabulary in a manner that is context rich, and use of an interactive Word Wall reinforces the reading and the use of science language.

Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.	Readings provide opportunities for teacher-led analysis of structure.
Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.	Readings provide an opportunity for teacher-led analysis of purpose.
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).	Readings support students in moving back and forth between text and visual information (e.g., "notice the shaded area in the diagram"), and some readings suggest that teachers reinforce this practice when previewing or reviewing readings.
Distinguish among facts, reasoned judgment based on research findings and speculation in a text.	This is best accomplished through suggested projects in which students pursue individual interests or go into more depth studying a topic related to class.
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.	Questions such as "How does what you read help you think about yesterday's investigation?" support students in integrating multiple sources of information. Videos and simulations, as well, are interwoven with reading and with hands-on investigations.
RANGE OF READING IN IQWST	
As students transition from learning-to-read to reading-to-learn, IQWST supports them with built-in strategies for students and teachers. IQWST does not provide texts at multiple Lexile levels, based on research that indicates (1) that students who are interested in a topic will choose to read well beyond their test-determined reading level, and (2) that reducing word length and shortening sentences (key strategies for decreasing reading level) can impair comprehension.	Rather than confine students who read below level to reading lesser content, materials suggest strategies for teachers to differentiate instruction so all students have opportunities to use the materials to develop as readers capable of using a range of written materials. Suggestions for students at the top of the grade level reading band encourage independent reading of texts beyond curriculum requirements, so no ceiling suppresses what IQWST students can achieve as readers and critical thinkers.

IQWST readings are integral to students' understanding of science concepts and enable teachers to simultaneously address reading- and writing-related concepts.

Readings

- Extend classroom learning by providing additional examples of principles and concepts encountered in class
- Review in-class activities to help students understand and retain main ideas and to support absent students with content they missed
- Elicit students' prior knowledge and draw on it in engaging ways
- Provide real-world connections that illustrate the value of science outside the classroom
- Use examples with which middle school students are likely to have personal experience or at least be familiar
- Embed questions, to which students write responses, supporting integration of reading and writing in the service of learning, as well as support students' active engagement as readers

Given that the ability to "read and comprehend complex informational texts independently and proficiently" is a lifelong literacy skill, IQWST materials are designed such that readings are intended to be done independently, outside of class time. The few exceptions, in which class time is specifically devoted to addressing some portion of a reading assignment, are clearly indicated in the materials.

Introducing Reading sections in the teacher materials often suggest that the teacher review the Getting Ready section of the student materials as a whole-class, oral activity, thus eliciting whole-class prior knowledge, engaging students in brief discussion, and setting a purpose for the homework reading. Reading setup could take as few as 2 to 3 minutes of class time, or as much as 10, depending on the teacher's purpose, students' abilities, and the nature of the individual activity, but in general, teachers should plan on three to five minutes to introduce the reading.

The Student Edition

Annotated versions of the student pages—in the Teacher Resource Book—provide the teacher with likely student responses or expected responses (including correct answers, where appropriate) as well as ideas for using those responses as formative or summative assessments.

Driving Question Notes and Scientific Principles Pages

The first few pages of every student edition are provided as note-taking space in which students can record both their own individual ideas that connect with the Driving Question, and those big ideas generated by the class. Students should record their own original questions and can add information about those as they progress through the unit. Scientific principles are big ideas that the entire class "arrives at" by the end of many lessons and that students record for ongoing reference. The teacher materials often suggest ideas to be recorded on these pages, but they can be used to record any information the teacher or students deem appropriate. Tracking of scientific principles is a way to ensure that the class articulates "what we know so far" as students progress through the unit; it has common language to draw on when constructing explanations or arguments that draw on these big ideas.

Activity Sheets

IQWST students experience phenomena in a problem-based, investigative context, typically guided by activity sheets for each lesson. These pages support students as they plan and carry out investigations, follow procedures, make predictions and compare them with what happened, organize and analyze data, and make sense of science. Activity sheets often include an opportunity for students to explain the *how* or *why* of a phenomenon, deepening students' understanding as they engage in scientific practices.

Having a student read the "What will we do?" section aloud is one strategy to provide students with an overview of activities in which they are about to engage. Read through the procedure with students, demonstrate it, highlight key components, or summarize briefly so that students conceptualize the big picture of what they are going to do. For example, tell students "You are going to observe two materials separately, and then observe them again after you put them together. It is important that you describe your observations in the table on your activity sheet. Then, you will write some questions about what you observed." Such review frames the activity for all students but is especially important for students who need to hear and not just read the procedure or who need to understand the big picture before making sense of the individual steps.

Homework

Some take-home assignments are designed as extension activities, typically requiring students to apply what they have learned to new contexts. These assignments reinforce in-class activities, providing independent practice focused on key ideas in each unit.

Using IQWST Readings Effectively

The Teacher Edition provides two primary ways of supporting students as readers in science by taking a brief amount of time to introduce the readings and consistently following up on readings in class discussion, as bell work at the beginning of class, or in a quiz-type format.

Introducing Reading

The best way to introduce readings is for the teacher to take the first few minutes of class time to generate interest. Materials typically include an Introducing Reading section with ideas. While spending a few minutes can have tremendous payoff for students, sometimes the teacher will be pressed to do something quick. Most important is that something is done to introduce the reading in order to engage interest, elicit prior knowledge, and set a purpose for reading.

Reading Follow Up

It is important to follow up the readings or other homework. Use the embedded assessments for grades or points or use them to generate follow-up discussion to begin a class period. Students held accountable for reading either through assessments or through in-class questions that require having read the materials in order to participate in discussion are more likely to read as homework. As they enter class, a simple way to do this is to have on the board an opening question that draws on what they read.

Writing in Science

LITERACY GOALS	AS ADDRESSED IN IQWST
Write arguments focused on discipline-specific content. (a) Introduce claims, distinguish from opposing claims, and organize reasons and evidence logically. (b) Support claims with logical reasoning and relevant, accurate data, and evidence. (c) Clarify relationships among claims, counterclaims, reasons, and evidence. (d) Maintain a formal style. (e) Provide a concluding statement that supports the argument.	One pervasive opportunity in IQWST is for students to construct evidence-based explanations of phenomena they investigate and to analyze and give feedback on the written explanations of their peers. In some units, this is taken a step further into argumentation, with written and oral defense of arguments: a key scientific practice supported when the unit content is conducive to argumentation. Reading and discussing writing can help students deepen their own understanding, hone their critical thinking skills, and support consensus-building or argumentation skills in a group.
Write informative/explanatory texts, including scientific procedures/experiments. (a) Introduce the topic clearly and organize ideas, concepts, and information as appropriate to achieving purpose. (b) Develop the topic with relevant facts, details, or other information. (c) Clarify the relationships among ideas and concepts. (d) Use precise language and domain-specific vocabulary to explain the topic. (e) Maintain a formal style and objective tone. (f) Provide a concluding statement that supports the explanation presented.	In addition to the information in the previous box, students write explanations in response to questions embedded in their reading materials and on activity sheets to conclude and make sense of investigations. Additional opportunities to write explanatory texts are often provided in the Differentiation Opportunities sections that precede each lesson.
Narrative skills—for example, write precise enough descriptions of step-by-step procedures they use in investigations that others can replicate them and (possibly) reach the same results.	Students write step-by-step procedures when they design investigations, engaging in an important scientific practice.
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	All explanations and arguments in IQWST are designed for a specific purpose and audience, and many other writing tasks define a purpose and audience so that students learn to write for different purposes.
With some guidance and support from peers and adults, students develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.	Process writing, as learned in ELA, is used throughout IQWST as students compose evidence-based scientific explanations and arguments, share them with peers, give and receive feedback, and revise.

Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently.	Opportunities to use the Internet to search for information and to inform writing are provided as Differentiation Opportunities to enable students to pursue curriculum-related topics in which they are keenly interested or for the teacher to assign topics to advanced students so that they might "go beyond" the curriculum's learning goals.
Conduct short research projects to answer a question (including a self-generation question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	Self-generated questions are at the core of IQWST, generated in the initial lesson in each unit, and then questions are continually encouraged throughout. Students write their questions on sticky notes, post them on a Driving Question Board, and are advised (or can be required) to investigate them independently.
Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.	In order to engage in the previously mentioned activity, students draw on multiple resources, including in-class activities and readings and Internet searches for other resources.
Draw evidence from informational texts to support analysis, reflection, and research.	Students draw on multiple resources including in-class activities and readings and Internet searches for other resources.

Summarizing is another valuable way to use writing. Summarizing requires determining and restating main ideas and findings. To support students in summarizing key ideas, provide practice for them to verbalize their thinking before writing or time to write about their ideas before sharing orally. For instance, before writing a summary of a reading, students could be asked the following: *How would you summarize this reading for students who were absent yesterday? What did they miss that they need to know?* After discussing, students will be better prepared to write summaries. Writing before sharing orally enables students to think and to process what they have learned before they are called upon to share ideas in class. These and other strategies support students as readers, writers, speakers, and listeners in the context of the science classroom.

In addition to the multiple opportunities provided for students to write to learn in IQWST lessons, activity sheets, readings, and home assignments, teachers can provide additional opportunities to meet the needs of individual students, many of which are suggested in the Differentiation Opportunities section that precedes each lesson.

Speaking and Listening

LITERACY GOALS	AS ADDRESSED IN IQWST
Engage effectively in a range of collaborative discussions (one-on-one, in-group, and teacher-led) with diverse partners . . . building on others' ideas and expressing their own clearly, (a) come to discussions prepared, having read required material, (b) follow rules for collegial discussions, (c) pose and respond to questions with elaboration and detail . . . connect the ideas of several speakers and respond to others' questions and comments with relevant evidence, observations, and ideas; and (d) acknowledge new information expressed by others and, when warranted, qualify, justify, or modify their own views in light of the evidence presented.	These behaviors are addressed in daily discussion, often as a follow-up to reading, to make sense of science during and after investigations and as a precursor to writing. Students given opportunities to talk about their ideas and those of others; to use talk as a way to think more deeply; and to critique claims, evidence, and reasoning orally are then better positioned to be able to write convincingly about their ideas. In addition, talking through ideas in this manner enables students to make sense of reading they have done or can set up reading as students read purposefully to determine whether their ideas were right, wrong, or somewhere in between.
Interpret and analyze information, main ideas, and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text, or issue.	As students engage with phenomena during investigations, their work requires interpreting and analyzing information that is visual/observational, verbal as expressed in both oral and written texts, and both qualitative and quantitative, requiring students to synthesize information from multiple sources.
Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.	Activities throughout IQWST that call for explanation or argumentation also call for students to share and to critique one another's ideas.
Present claims and findings, sequencing ideas logically and emphasizing salient points in a focused, coherent manner; use appropriate eye contact, adequate volume, and clear pronunciation.	Activities throughout IQWST that call for explanation or argumentation, as well as modeling, also call for students to present their ideas to a partner, a small group, or to the whole class.
Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.	Visual displays, especially models that accompany explanations and arguments, are constructed and shared in every IQWST unit.
Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.	The primary manner of speaking and listening in IQWST is presenting ideas for comparison with others' ideas and both giving and receiving oral feedback.

Classroom Culture

Establishing a culture in which students actively participate in "talking science" is at the core of IQWST, but it is challenging for both teachers and students. By the time students have reached the middle grades, they know a great deal about what it means to "do school." They raise their hands, do so only when they think they have the right answer, and respond to teacher-posed questions rather than to peers' ideas. In an IQWST classroom, students ask questions that arise out of individual interests or concepts about which they are confused. They ask questions of other students, as well as the teacher. Science discussions promote active engagement in science learning such that everybody expresses their understanding and learns from each other. The goal is for students to develop as thinkers and problem solvers through participating in thoughtful talk about core content.

Sharing ideas openly, asking questions of one another, defending one's ideas, and not having right answers challenges many students, as well. Students who are successful when reading and answering questions may not be comfortable discussing and exploring alternative ways to explore concepts. Students may be uncomfortable participating in discussions if they are unsure of the correct answer or may be uncomfortable with the idea that multiple responses may be considered correct at a given time in the process of learning. Students who are successful doing activities and discussing their reasoning may struggle when they are required to write about their ideas. Students who have looked to the teacher for answers and guidance may find it unusual that they need to question another student or provide rationale for their responses.

Establishing a classroom culture wherein students feel comfortable sharing and discussing with each other and feel confident about participating actively begins on the first day of class. Since IQWST may introduce a new manner of discussion for students, the teacher will need to model sharing, listening, and learning with students by demonstrating the value of contributions, not just correct answers. The primary goal of oral discourse is for students to articulate their own understanding and to listen and respond to each other. This goal is assisted when the following occurs:

- All students are provided opportunities to participate.
- All students are encouraged to participate.
- Students are encouraged to think together, rather than only speak, if they think they have the correct answer.
- Students see the value in wrong answers for figuring things out.
- Students are provided opportunities to write their responses before sharing aloud.
- Students use information in readings as a springboard for discussion.
- Students listen carefully to others and respond to others' ideas.

Small-group discussions are an integral part of the inquiry process in IQWST. They provide the best opportunity for students to learn from each other and interact with their peers as well as with the teacher. It is important that all students have an opportunity to participate, express their ideas, listen to one another, and respect others' ideas. Developing a classroom culture in which this is the norm may take time, especially if this is not what students are accustomed to in other classroom settings.

Teacher Supports

IQWST lessons support teachers by providing scaffolding to help facilitate conversation. Teacher supports include a list of possible questions or prompts a teacher may use or adapt, as needed, possible student responses, information about what student responses might suggest about their understanding, and ideas about how to address those ideas. The lessons support the teacher in creating a culture of science discourse by providing question stems such as these:

- What can you add to make this idea clearer?
- How does this idea compare to the idea of the previous speaker?
- What can you add to expand on what was just said?
- How can you summarize our conclusions?

Three Types of Discussion

IQWST lessons identify discussions by type to assist teachers in recognizing the structure of the discussion and conducting the discussion according to the guidelines for each.

In IQWST, brainstorming is any discussion with the purpose of generating and sharing ideas without evaluating their validity. Prompts provided for all brainstorming discussions are suggestions meant to encourage students to express their ideas. It may be useful to record ideas on the board, on a computer, or on a transparency so that students can see what has been said and can build on others' ideas. A photograph of notes recorded on the board, a printout, or a transparency can be attached to the Driving Question Board as a reminder of the activity.

1. Discussion: Brainstorming
   Purpose: To articulate and share ideas without evaluating their validity.
   - All ideas are accepted in brainstorming.
   - Ideas are captured and recorded as they are generated.
   - Brainstorming prompts include the following:
     - What have you observed or experienced?
     - What do you think about when you hear the word . . . ?
     - What do you know about . . . ?
     - Who has a different way of thinking about this topic?
   - Follow-up can include, as appropriate, such questions as the following: Where does that idea come from? How do you know? Where have you heard/seen/experienced that before?
2. Discussion: Synthesizing
   Purpose: To put ideas together or assemble them from multiple activities into a coherent whole.
   - Discussions may include making connections to personal experiences, to the Driving Question, and to other lessons or content areas.
   - Synthesizing prompts include the following ones:
     - How does this connect to . . . ?

- o How does this support the Driving Question?
- o How does this help us think about the activity we did yesterday?
- o What do we know about this topic so far?

In IQWST, the purpose of a Pressing for Understanding discussion is to get students to think more deeply and to make sense of their experiences. Some questions can lead to a simple answer, others to a deeper, more thoughtful answer. Learning through inquiry encourages students to think more deeply but only if their thinking is scaffolded until they learn to think in terms of how and why, to make connections, to analyze, and to synthesize. Probing questions such as *Why do you say that?, What makes you think that?,* and *How do you think that works?* invite students to think more deeply and, over time, establish a culture in which doing so is the norm in science class.

3. Discussion: Pressing for Understanding

   Purpose: To figure things out or make sense of readings or activities while going deeper and beyond surface answers.

   - Discussions may involve respectful challenge, debate, or arguments in which students justify their ideas.
   - When pressed, students may revise their previous ideas as they learn new information that shows the limitations of their previous understandings.
   - Pressing for Understanding prompts include the following:
     - o How do you know? What evidence supports that idea?
     - o Why does our old model not work to explain this new phenomenon?
     - o How could we figure this out?
     - o How does . . . compare to . . . ?
     - o What new questions do you have?

THE LANGUAGE OF SCIENCE: VOCABULARY

New Meanings, Familiar Words

Science as a discipline is known for its challenging vocabulary; thus IQWST lessons contain supports to help students develop deeper understanding of science concepts, including how, when, and why particular language is used. Students are engaged in thinking about the language of science in multiple ways.

IQWST takes a research-based, contextual approach to science language, stressing the repeated, ongoing, pervasive use of new words in oral and written discourse, acknowledging that language and conceptual understanding develop hand-in-hand. Science words are taught as they are needed. Typically, after a concept has been encountered, it is then given a label (the vocabulary word). A primary support for students occurs when teachers use science vocabulary frequently and appropriately and guide students to do so as well.

One of the hallmarks of successful readers is their ability to understand word meanings as they occur in varied contexts. When the teacher uses science vocabulary in context and calls attention to similarities and distinctions between words, all students are supported in building their science vocabularies. Students' everyday understanding can help or hinder their understanding of the uses of many words in science. Words like *absorb* and *reflect* have everyday uses that are consistent with their meanings in science, so linking the everyday to the scientific is likely to be helpful. However, words like *volume* and *mass* or words that name scientific practices such as *modeling* or *explanation,* have everyday meanings that may not help students understand the meaning in science. In those cases, making differences explicit supports students in learning multiple uses of words, including specific uses in science.

Simple routines used before students read new text can help students recognize and use science language as they read, write, and discuss their developing understandings.

Prereading

Before asking students to read independently, the teacher can identify words that will be difficult for the class. Words the teacher anticipates will be difficult can be rehearsed by displaying them (on the board or on a Word Wall), pronouncing them, and providing a snapshot definitions aimed only to help students recognize the words when they encounter them in the context of written text. This scaffolding helps students move words from listening and speaking vocabulary to their reading and writing vocabulary.

Building Vocabulary

Many science words have common prefixes, suffixes, or root words. Building a list of words with similar word parts allows students to see, define, and make connections between words such as *biology* and *ecology*, especially when connected to biosphere, ecosystem, eco-friendly, biochemical, and biography, among others.

For teachers required to do more intense vocabulary study at the middle school level, strategies should support students in developing deeper understanding of science concepts, rather than simply memorizing textbook-style definitions. Although writing vocabulary words in sentences is common school practice, it has not been shown to promote science vocabulary learning. Thus time is better spent engaged in tasks that use science vocabulary: constructing oral and written explanations and arguments, composing brief summaries, and answering questions that require both critical thinking and the use of appropriate vocabulary.

Interactive Word Wall

Keeping a space in the classroom to post new science language, as new words are encountered, provides students with multiple exposures to new words and allows them to refer to the Word Wall when communicating ideas, formulating questions, or writing (and learning to spell science vocabulary). Having words posted allows the teacher to gesture to the Word Wall during discussion to support students in using science language in their talk. Words written on sentence strips can easily be moved to increase opportunities for connecting words in various ways, grouping them or creating concept maps. Word Walls may be enhanced by short definitions or by visual representations, as well. Students with artistic ability or who like to draw, or who learn by the act of creating representations may create visuals to post on the Word Wall along with new words. Most important is that the classroom is language rich, providing students with ongoing exposure to discipline-specific vocabulary, which supports them as readers, writers, and critical thinkers in science.

ASSESSMENTS

Embedded/Formative Assessments

Formative assessment opportunities are embedded within IQWST lessons. They occur during discussions, activities, and readings and can be used to gauge students' understandings and developing science ideas in the moment. Formative assessments used regularly during the learning process enable the teacher to determine whether concepts need to be revisited, whether an optional activity would be beneficial for student learning, whether discussion should be extended or guided differently in order to support student learning, or whether some or all students would benefit from additional support. Formative assessments also enable teachers to provide explicit feedback to students on their ideas, so students can know in what ways they are on track toward meeting learning goals. Formative assessments also enable teachers to differentiate instruction in response to students' current understandings. Questions embedded in readings and as suggested prompts for discussion include possible student responses and, where appropriate, correct answers. When using embedded assessments to gauge students' understanding, analyze responses by listening for students'

- the ability to connect previous ideas with new content;
- the ability to summarize ideas accurately;
- current content understanding, as it will lead to meeting learning goals; and
- developing use of appropriate science language.

Summative Assessments

Many of the embedded assessments, while designed for formative use, may be assigned points or letter grades. Any written response in the student books may be seen as a summative opportunity. An option is to invite students to submit their one "best response" to questions in a lesson or their best evidence-based explanation or other revised response for a grade. This practice acknowledges that motivation, interest, and understanding vary from day to day and recognizes that assessing one's best work helps students be more aware of their own performance and what constitutes "good work" in science. IQWST also provides a bank of questions, available electronically, and in Word format, that teachers may draw from to customize quizzes and tests. Questions may be used as they are or adapted to best match instruction or to meet students' needs (i.e., differentiation).

SAFETY PRACTICES

Laboratory investigations excite students about the practice of science and lead to reflective discussions about investigation design and the real work of scientists. With investigations comes the need to teach laboratory safety and practice safety precautions with middle school students who may be new to lab experiences.

Science teachers are expected to take all possible actions to avoid accidents in the laboratory setting and to monitor labs for hazardous chemicals or flammable materials. This includes standard safety practices that include housekeeping to keep the laboratory areas clear of clutter and prohibiting unsupervised access to areas where electricity, chemicals, or heat sources are used.

Teachers should provide information about, and practice, laboratory evacuation drills. Gas and electricity should be shut off during any drills or whenever the class is leaving the lab. All exits must be kept free from obstructions, and no materials should be stored outside of the lab storage room. Safety rules should be posted in the room and reviewed with students prior to lab work. If the teacher, school, or district has specific science rules, those should be posted.

IQWST lessons contain specific safety information at the start of each lesson and throughout the lessons for easy reference for teacher and student. MSDS sheets should be consulted for appropriate use of all chemicals.

Science Lab Rules

There are many science rules to ensure safety in the laboratory. IQWST lessons have specific science cautions through each lesson to guide teachers and students, but middle school students, because of their inexperience with science labs, may need to be aware of certain safety procedures that include the following:

1. Clothing and Hair—Loose or baggy clothing, dangling jewelry, and long hair are safety hazards in the laboratory.
2. Cold and Heat Protection—Cold or hot materials should only be touched with hands protected by items such as safety tongs, safety mittens, or rubber gloves. In some instances, only the teacher should handle materials at extreme temperatures (e.g., dry ice).
3. Food—No eating, drinking, or use of cosmetics should occur during lab time. Even familiar substances used in activities (e.g., marshmallows for molecules) should not be consumed, as they may be contaminated in the lab setting.
4. Glass Caution—Glass should be used cautiously, and students should report any chipped, cracked, or scratched glassware should such occur during a lab activity.
5. Housekeeping—Work areas should be kept clean at all times, with backpacks, books, purses, and jackets placed away from lab tables.
6. Washup—Hands should be washed with soap and water before and after laboratory work. Students should not touch their faces or hair with either bare or gloved hands that have handled lab materials.

7. Safety Equipment—Personal protective equipment such as goggles, gloves, and aprons should be used as appropriate for the activity.
8. Allergies—All allergies should be noted for students and a plan put in place if peanuts, peanut oil, latex, or other known allergenic items are used in the lab. For example, although gloves and goggles provided in IQWST materials are latex-free, some units use balloons, which students with latex allergies should not handle.
9. Sniffing—When directed to "sniff" in the lab, students should be taught to follow the teacher's directions for "wafting" odor to the nose.

These rules are general and should always be followed in a lab situation. IQWST provides a letter to parents that discusses science safety rules. If a school or district has another science letter, and/or additional safety rules, teachers should use the district letter and follow all school or district guidelines for safety in the science lab. For additional safety information, consult the NSTA safety portal at http://www.nsta.org/portals/safety.aspx.

SAFETY LETTER

Dear Students, Parents, and Guardians:

Middle school science consists of engaging topics for students to investigate in a lab setting. However, any science activity may have potential safety issues if not conducted properly. Safety in the science classroom is an important part of the scientific process. To ensure a safe learning environment, a list of rules has been developed and discussed with all students because science rules must be followed at all times. Additional safety instructions will be given for each activity. Please discuss the safety rules with your child and return the bottom of this letter.

No science student will be allowed to participate in science activities until the student and a parent or guardian have acknowledged their understanding of these safety rules by signing this document.

Science Safety Rules

1. Conduct yourself in a responsible manner at all times in the science room.
2. Follow instructions carefully. Ask questions if you do not understand the instructions.
3. Use equipment (e.g., scissors and sharp items) only as directed by the teacher.
4. Perform only approved experiments.
5. Never eat, drink, chew gum, or taste anything in the science lab.
6. Keep hands away from face, eyes, and mouth while using science materials. Wash your hands with soap and water after the activity.
7. Wear safety goggles when instructed. Never remove safety goggles during an experiment. There are no exceptions to this rule!
8. Clean all work areas and equipment, and dispose properly of any waste materials.
9. Report any accident (spill, breakage, and so on), injury, or broken equipment to the teacher immediately.
10. If you have allergies, it is important that your teacher knows about them and that you avoid handling materials that could cause problems. For example, if you are allergic to latex, you can participate in activities that use balloons, but you should not be the one to handle the balloons.

SAFETY AGREEMENT

Dear Students, Parents, and Guardians:

We are providing the Science Safety Rules to keep you informed of the school's effort to create and maintain a safe science classroom/laboratory environment for all students.

Your signature on this letter indicates that you have read the Science Safety Rules, have reviewed them with your child, and are aware of the measures taken to ensure the safety of your son/daughter in the science classroom.

Parent/Guardian Signature: ______________________________

Student Signature: ______________________________

Date: ______________________________

Important question – Does your child have any health issues or allergies? If yes, please list them here.

Unit Overview

What Makes the Weather Change?

This Earth Science unit focuses on what causes variation in local weather events and global climate patterns by developing a model of flow of matter and energy through the atmosphere.

DRIVING QUESTION: WHAT MAKES THE WEATHER CHANGE?

What Makes the Weather Change? is the Driving Question that organizes and motivates various activities throughout the unit. The scientific principles students learn, and the inquiry practices in which they engage, are instrumental to understanding and answering this Driving Question. Students complete a number of investigations and create models to explain weather concepts. There are two learning sets in the unit's instructional sequence, with eight lessons.

LEARNING SET 1: WHAT CAUSES A STORM?

Students begin by drawing on their everyday experiences with weather to identify the conditions they need to investigate that contribute to weather events like a storm. Students first consider how air at the surface of Earth is heated. Students draw on their understanding of energy from the IQWST PS2 unit to analyze what happens to matter and energy to cause surface air to be heated. Students create a model that explains how the air at the surface is heated through a sequence of energy transfers from the sun to the Earth's surface, energy conversion from solar to thermal energy, and energy transfer (through conduction) from the ground to the air. Students then investigate what happens to the air after it is heated. Students investigate the movement of air masses at different temperatures and attempt to explain why hot air rises. They develop a model of convective currents and revise their models to show the movement of matter and energy in a storm.

After investigating additional weather conditions, including pressure, humidity, and lift, students develop and revise a model of a storm that shows what happens to the matter and energy before, during, and after a storm. They then use their model to explain patterns in the weather condition data from a real storm in the Midwest. At the end of this learning set, students can explain the changes that occur in local weather patterns from day to day. They are left with the question of explaining why the weather varies from one location to another on Earth.

LEARNING SET 2: WHY IS WEATHER DIFFERENT FROM PLACE TO PLACE?

Students begin Learning Set 2 with a question about how location affects weather. Students have constructed and tested a model that explains a storm and how the conditions affect daily weather, but students have also determined that their models cannot explain the patterns in the data that show that weather conditions vary by location on Earth. Students determine how temperature varies by latitude. To investigate this finding, students analyze the number of hours of daylight a city receives as well as its temperature. Students consider differences in hours of daylight, which their model says would lead to temperature differences, but then reject that factor as a possible explanation for the relationship between latitude and temperature. Students then collect data to analyze whether the shape of Earth affects temperature. This activity raises the question about the angle at which light hits Earth and whether that affects temperature. After discovering that the angle at which light hits an object affects the intensity, students construct an explanation about why temperature varies at different latitudes. Students use visualizations of surface temperature at two different times of the year (January/July) and observe that the warmer areas shift north in the summer and south in the winter. Their previous explanation cannot account for this, and they engage in a series of simulations to explore the idea of a tilted Earth. Students construct a model that explains seasonal variations in temperature. In the culminating activity, students use all of the evidence they have collected, as well as the scientific principles they have developed, to explain why two cities in opposite hemispheres vary in their weather patterns.

UNIT CALENDAR

Unit Driving Question – What Makes the Weather Change?

Learning Set 1: What Causes a Storm?	
1–2 Class Periods	**Lesson 1 – What Is Weather?**
	Activity 1.1: Identifying Weather Conditions around the World
	Activity 1.2: Setting Up the Driving Question Board (DQB)
	Reading 1.2: What Can Clouds Tell Us about Weather?
2–3 Class Periods	**Lesson 2 – What Makes Air Hot?**
	Activity 2.1: It Is Heating Up
	Activity 2.2: A Little Heat from Me to You
	Reading 2.2: Why Does Conduction Matter?
3 Class Periods	**Lesson 3 – What Happens to the Hot Air?**
	Activity 3.1: How Do Differences in Temperature Affect Air Masses?
	Activity 3.2: What Happens When Air Is Heated or Cooled?
	Activity 3.3: Why Heat Rises
	Reading 3.3: Why Learn about Convection?
2–3 Class Periods	**Lesson 4 – Where Does the Energy Come from in a Storm?**
	Activity 4.1: Constructing a Barometer
	Activity 4.2: Temperature Difference and Movement of Air Masses
	Activity 4.3: Is a Storm Cloud Different from Other Clouds?
3 Class Periods	**Lesson 5 – What Can Weather Maps Tell Us?**
	Activity 5.1: What Can Weather Maps Tell Us?
	Activity 5.2: Creating an Isobar Map
	Reading 5.1: How Do Scientists Get the Data?
3 Class Periods	**Lesson 6 – Does the Storm Model Fit Data from a Storm?**
	Activity 6.1: Can We Identify Patterns in Data?
	Activity 6.2: Can the Storm Model Explain the Data?
	Reading 6.2: Is It Going to Snow or Rain or…?
Learning Set 2: Why Is Weather Different from Place to Place?	
4 Class Periods	**Lesson 7 – Why Does Temperature Vary in Different Locations?**
	Activity 7.1: How Can We Compare Cities on Earth?
	Activity 7.2: Do the Number of Daylight Hours Vary in Different Locations on Earth?
	Activity 7.3: Does the Earth’s Shape Affect Temperature?
	Activity 7.4: Does the Angle that Light Hits the Earth Affect Intensity?
	Activity 7.5: Can We Explain the Pattern in the Data?
	Homework 7.5: Do the Data Match the Explanation?

4–5 Class Periods

Lesson 8 – What Else Is Affecting Temperature?

Activity 8.1: Does the City Data Match the Visualizations?

Activity 8.2: How Does the Earth Move?

Reading 8.2: Day and Night

Activity 8.3: Does a Tilted Earth Explain the Seasons?

Reading 8.3: Seasons of the Year

Activity 8.4: Why Is the Temperature Not the Same Everywhere?

ES2 SCIENTIFIC PRINCIPLES

1. Light energy from the sun is mostly transmitted through the air before reaching the ground, and the ground absorbs some of the light energy that reaches it.
2. Molecules transfer thermal energy from one end of an object to another and to other objects by collision between molecules that transfer the kinetic energy of one molecule to another (conduction).
3. The air at the Earth's surface is primarily heated by the transfer of thermal energy from the ground below it.
4. Less dense air rises when surrounded by more dense things. The more dense air moves in to take its place. The movement of air masses is called *convection*.
5. Air pressure at a location is related to the total weight of the air above that location. Low-density air columns have low pressure and high-density columns have high pressure.
6. Large air masses can behave as closed "systems" for long periods of time before reaching equilibrium with the surrounding air masses. A front is the boundary between these large air masses.
7. Air masses move when high-pressure air pushes into the space of lower-pressure air. At the surface, higher differences in pressure over smaller distances result in stronger winds.
8. Air masses move when more dense air slides underneath less dense air, causing the less dense air to be lifted upward. This less dense air is unstable as it is forced upward. It transfers energy to the surrounding air and cools as it rises.
9. Movement of air masses causes changes in weather in predictable ways.
10. Intensity of light varies depending how far north or south of the equator you are and how long the light shines on a place.
11. Temperatures vary in a predictable pattern depending on latitude.
12. Intensity differences explain why temperatures vary in the same pattern.
13. The Earth is tilted on its axis, causing light to hit the Earth more intensely and for longer periods of time in different parts of the Earth during the year. This causes the seasons.

Lesson 1

What Is Weather?

PREPARATION

Teacher Background Knowledge

Weather Conditions and Weather Events

- Weather conditions refer to the atmospheric conditions that compose the state of the atmosphere: temperature, wind, clouds, and precipitation.
- Weather events are combinations and interactions of weather conditions that occur at a specific place and time. Tornadoes, hurricanes, and other storms are weather events. They are specific combinations of temperature, wind, precipitation, and clouds occurring at a specific time.

Setup

Specific instructions for activity setup are embedded within the lesson.

Materials – Activity 1.1 (Storm Sounds)

For the Class

- Sounds of rainstorm, blizzard, tornado, hurricane, and so on* (These clips should last about five minutes, so that there is enough time to identify various weather conditions. Search for sounds on the Internet.)

*This item is not included in the kit.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

World Map

- Use a world map in the classroom to identify the location of the example cities. Groups can mark the location of their city with a colored sticker or pin.

- This map will help students begin to see the global nature of weather conditions and events. Students return to this map in Lesson 2 in order to investigate the second part of the Driving Question: Why Is Weather Different from Place to Place?

Local Weather Data

How you handle this project depends on the amount of available space in the classroom.

- A chart can be kept in the classroom for recording the weather each day. Groups can be responsible for one day each or for a week at a time.
- For homework each night, students can individually record the daily data. They could watch a weather report on television, use the Internet, or read a newspaper.

Lesson 1

What Is Weather?

TEACHING THE LESSON

Performance Expectations

Students will

- analyze data to determine the conditions involved in defining weather events.
- generate questions about the cause of weather phenomena in terms of transfer of energy and flow of air and water.

Overview

Introducing the Lesson

Brainstorm what weather is and what conditions make up weather events.

Activity 1.1

Analyze data from world cities to determine that weather conditions appear everywhere and are the same.

Activity 1.2

- Introduce the Driving Question and Driving Question Board.
- Post questions on the Driving Question Board to be used throughout the unit.

Building Coherence

This unit focuses on what happens to the matter and energy during a storm and other weather events. There are strong connections to units IC1 and IC2. This unit also connects to students' everyday experiences with weather. In this lesson, students are introduced to the conditions that interact to produce various weather events.

Timeframe

1–2 Class Periods

Introducing the Lesson

As students enter the classroom, have the weather sounds playing. After about five minutes, make a list on the board of the sounds students heard. Ask students to categorize these sounds (*weather*).

Suggested Prompts

- What is weather?
- What makes up the weather?
- What exactly did you hear? What kinds of weather were represented? (*Possible student responses might include the following: storms, snow, rain, wind, clouds, tornado, and so on. Record all reasonable responses about the weather.)*

Be sure that the list includes weather events, such as snowstorms, hurricanes, tornadoes, and so on, as well as conditions such as rain, snow, temperature, clouds, and wind.

Explain to students that in this unit they are going to try to predict and explain something that happens all around them—weather. In order to do that, they need to figure out what weather is.

Suggested Prompts

- What conditions make up the weather?
- Do you think these conditions and events are the same everywhere in the world?
- How could we find out?

In the next activity, students will look at weather reports (data) from cities throughout the world in order to compare conditions and events, and establish a common list of conditions to investigate.

Materials – Activity 1.1

For Each Group

- Data sheets for selected cities (located in the student edition)
- Buenos Aires, Argentina
- Atlanta, Georgia
- Oslo, Norway
- Belem, Brazil
- Singapore
- Ushuaia, Argentina

For Each Student

- Activity Sheet 1.1

Activity 1.1 – Identifying Weather Conditions around the World

In this discussion, students will identify conditions that change and interact to produce weather events. The goal of this learning set is to make predictions about a weather event (storm). To do this, the variables that contribute to the event need to be identified.

Ask: "Who has listened to a weather report? What are some details you remember the person reporting? Project the weather report for the current conditions for your city (not the forecast)." Ask students the following questions.

- What details were included in the report? (*Students should list temperature, wind, clouds, and precipitation. In addition, they may add humidity, dew point, or wind chill, depending on the season and your location.*) List these conditions on the board. Students will return to this list and use it to help create the Driving Question Board later in the lesson.
- Are these conditions the same every day and throughout the year where you live? (*It is important to identify that while the conditions are the same, they vary throughout the year.*)
- Do you think these conditions can help predict the weather?

In this activity, groups will be given weather data for five consecutive days for one city, along with the forecast for those five days. These cities are located in various parts of the world. The sample cities are the following: Buenos Aires, Argentina; Atlanta, Georgia; Oslo, Norway; Belem, Brazil; Singapore; and Ushuaia, Argentina. Students will use data from these same cities again in Lessons 6 and 7.

In addition to analyzing the weather conditions in the sample cities, the class should track conditions locally as well. It is important throughout this unit to make connections between what students are studying in the lesson and local events and conditions. That connection to their everyday lives makes the science more relevant.

Analyzing Weather Conditions

Assign students to six groups and distribute weather data for one of the cities to each of the groups. Each packet of data contains a brief description of the location of the city and weather reports for five days, as well as the forecast. The weather reports for each city are from the same five days in February 2011. Using a week of data allows students to see that weather is not the same everywhere, as well as how weather can change in a specific place. Students should examine the data in order to determine the weather conditions used to help predict the weather.

Have each group plot the location of their city on the classroom map. Also indicate the location of your home city, since the class will be tracking local weather data as well. Have students share the weather conditions they saw in each of the cities. Use the list of conditions on the board and add any new ones that students found. Discuss what they found.

Suggested Prompts

- Do the same conditions appear on all of the reports? (*These should be the conditions already listed on the board, with possibly the addition of dew point and/or wind chill, depending on the time of year. Make sure the following conditions are listed: temperature, wind, clouds, precipitation, and humidity.*)
- Do they have the same values everywhere? (*It might be hotter in Atlanta, Georgia, than in Oslo, Norway.*)
- Do the same weather events occur everywhere? Is it raining in all cities? Do some cities have rain and others snow?
- Were the conditions in your group's city the same every day, or did they change? (*Since these conditions do not remain the same in all weather events, they should be identified as variables.*)
- Do these conditions always produce the same event? Do they always create a storm?
- Do you think changes in these conditions help us predict the weather? Why?

When concluding this activity, students should understand the following points.

- The same weather conditions appear everywhere but do not necessarily have the same values. These are identified as *variables*.
- Weather events are different in different places, even at the same time of the year.
- Weather conditions at the same location vary from day to day.
- Students have identified conditions that make up weather. *Weather events* is a phrase used to describe what's happening with these conditions at a particular time and place.

With this definition of weather, ask students if they have any ideas about why these conditions and events vary from day to day (at a given place) and from place to place. Students are not expected to know the answer. This question is meant to prompt them to create the Driving Question for the unit: What Makes the Weather Change? Write this question on the Driving Question Board. This is the question students will try to answer in this unit. In the next activity, students will brainstorm questions they have about weather conditions and events, and set up the Driving Question Board.

Activity 1.2 – Setting Up the Driving Question Board (DQB)

In several places there were storms, but why weren't storms everywhere if the same conditions are everywhere?

Suggested Prompts

- Why does this happen?
- Are these conditions causes of the weather, effects of the weather, or both?
- Do you think these conditions interact in some way to create weather events?

Students saw that the weather was not the same every day. This is a good point to link to local conditions. Ask students the following questions.

- Is the weather here the same today as it was yesterday? (*If a storm recently occurred in your area, or one is expected to occur in the next few days, link that to changing conditions.)*
- Is there a pattern to when storms occur in our area? (*Patterns like thunderstorms in the summer on hot days, snow in the winter, and floods in the spring are all possible patterns that students may identify. They should begin to connect the idea of interacting conditions occurring in specific patterns. They will develop this idea throughout the unit in order to answer the Driving Question.*)

Discussion – Brainstorming

Purpose

Develop questions about why weather varies and what causes weather.

Suggested Prompts

- Why do you think weather varies?
- What causes weather?
- What was happening in each of these storms we observed at the beginning of class? What conditions were present? (*There was wind, precipitation—either snow or rain—and clouds.*)
- Do you think these conditions can help predict what will happen with the weather?
- What do you know about wind? (*It is moving air.)*
- What is temperature? (*Temperature is a measure of the thermal energy of matter.Thermal energy is the kinetic energy of the random motion of particles in an object.)*

Students may have the (previous) understanding of temperature (IQWST IC1 and PS2). Review or establish that understanding. Ask what material students are talking about when they give the temperature in a weather report (*air*).

Ask: "What is precipitation?" (*Precipitation is water that has evaporated and moved into the atmosphere and then falls as rain or snow, for example*.) Students should be familiar with the hydrologic cycle if they studied the IQWST ES1 unit.

Have students think about the questions they have about what happens with these conditions to cause a storm. Have them write their questions on sticky notes. Students will post the notes on the DQB when they are finished. Some possible questions include:

- What causes the wind in a storm?
- Why is the wind stronger in a storm?
- Why does it stop after a storm?
- Why is it windy some places but calm in others?
- What causes the temperature to change?
- Where does the energy come from to cause the temperature to rise?
- Why is it hotter in some places and cooler in others?
- Where does all the water (or snow) come from in a storm?
- Why is it sometimes rain and sometimes snow?
- Is rain just increased condensation?
- Why does it rain more in some places than in others?
- What is air pressure? Why is it part of the weather report?
- Why is elevation on the weather report?

Students have seen that all of these conditions change, and they are trying to figure out how those changes affect weather. Refer to the definition of temperature that students gave earlier (*a measure of the thermal energy in matter*).

Suggested Prompts

- What matter are we talking about when we refer to temperature when we talk about the weather? (*The matter is air.*)
- Is there matter in any of the other conditions? (*Students should suggest that the wind is moving air—that is, matter. Also, precipitation is matter, in the form of water.*)
- If both air and water are moving, what is happening to each of these materials (matter)? (*Air moving is wind, and water moving in and out of the atmosphere is precipitation.*)
- What is necessary to make these conditions occur? (*Energy makes these conditions occur. Students may have learned that energy can be transferred [IQWST PS2].)*

If you can figure out what is occurring with both the matter and energy in each of these conditions, then you can figure out what is happening in a storm. Return to the DQB and remind students of the Driving Question: What Makes the Weather Change? Turn to the DQB, and have students post their questions under the appropriate condition.

Sample DQB: What Makes the Weather Change?

CONDITIONS	ENERGY QUESTIONS	MATTER QUESTIONS	WHAT WE LEARNED
Wind **Temperature** **Precipitation** **Clouds** **Humidity** *(This may not be added until later unless students raise it as a condition on their data sheets.)*			
Air Pressure			

Students have identified two key elements that they need to consider in order to figure out what occurs with weather and storms—in particular, matter and energy. One of the conditions students identified was temperature. They identified that temperature was the measure of the thermal energy in the air. Ask students if they have any ideas about why temperature changes. In the next lesson, students will investigate this question.

Introducing Reading 1.2 – What Can Clouds Tell Us about Weather?

Students may be familiar with weather patterns in the location where they live, but often students think that the weather patterns they experience are the same patterns that everyone experiences all over the world. Ask students why they think it might be helpful to know about weather patterns for a region. Who might want this information, and how would they use it? This will get students thinking about patterns in general and the reasons that scientists, and many people all over the world, care about patterns—specifically weather patterns. You can also use the Getting Ready question in the reading to help students to think about how they use patterns in their lives.

Lesson 2

What Makes Air Hot?

PREPARATION

Teacher Background Knowledge

Systems

- In the IQWST LS2 unit, students will revisit the concept of systems. At this point, they need to know that a system is a unit of interacting parts.
- In this unit, they will be exploring the flow of matter and the flow of energy through weather systems.

Earth's Surface

Encourage students to use the term *Earth's surface* rather than ground. Earth's surface is inclusive of ground, bodies of water, and objects on Earth. All of this matter absorbs solar energy. This is important for students to understand when talking about solar energy heating the Earth. If the term *ground* is used, students can think that the only thing that heats up is the dirt and soil.

Energy Transfer from the Sun

This unit focuses on students' understanding of the basic flow of matter and energy that affects weather/temperature. Students may have seen very complex illustrations that show radiation being reflected and absorbed by the clouds and air. This unit only focuses on the absorption of energy by objects (matter) on Earth's surface. This accounts for over 51% of the radiation from the sun. The more complex ideas around solar radiation will be handled in high school.

For your information, the approximate distribution of solar radiation is as follows.

- 4% is reflected back to space by the Earth's surface.
- 20% is reflected back to space and scattered by clouds.
- 6% is scattered by the Earth's atmosphere.
- 19% is absorbed by clouds and the atmosphere.
- Approximately 51% is absorbed and converted to thermal energy by the Earth's surface.

Setup

Activity 2.2

This activity uses pea-sized solid vegetable shortening balls. You may make these ahead of class or have students make them during the setup time.

Safety Guidelines

A heat source is used in Activity 2.2. Review lab safety procedures when using hot objects.

Differentiation Opportunities

You may do the second activity as a teacher demonstration or as a group activity. Depending on the amount of time in the class period, you may choose to set up part or all of the apparatus prior to class.

Lesson 2

What Makes Air Hot?

TEACHING THE LESSON

Performance Expectations

Students will

- construct and defend an explanation for the spread of heat through a material, or between materials, in terms of transfer of kinetic energy.
- construct and defend a model of how air is heated by the sun that includes conversion of solar energy to thermal energy in Earth's surface and the transfer of thermal energy via conduction from Earth's surface to air.

Building Coherence

The purpose of this lesson is to explore the concept of air temperature and to develop an understanding of how the atmosphere is heated. In the previous lesson, students determined that temperature, when referring to weather, is the measure of thermal energy in the air. They will draw on concepts of energy transfer (developed in the IQWST PS2 unit) to explain two ways the atmosphere is heated.

Timeframe

2–3 Class Periods

Overview

Introducing the Lesson

Establish the idea that weather is a system and will be studied as a system.

Activity 2.1

Create a model of how the air is heated.

Activity 2.2

- Use an apparatus to determine how the air is heated.
- Construct a consensus model of how the atmosphere is heated.

⚠ Students will use a candle and have a paper towel nearby. Stress appropriate safety precautions.

Introducing the Lesson

Discuss with students what they have learned about interactions.

- What does it mean when objects interact? (*When two or more objects have an effect on one another, it is called an interaction.*)

If students did the IQWST LS1 unit, they learned that an ecosystem is the interactions between biotic and abiotic factors in an area. Other examples of systems could include the human body system, an electrical system, and the solar system. In this unit, weather and storms are called a system because the conditions of which they are made interact.

In Lesson 1, students identified matter and energy as two key elements of weather. Students will be tracing matter within the system and also tracing the flow of energy through the system by looking at the conditions that interact to create the system.

Review the DQB, which should now contain these items:

- Wind—Moving air.
- Temperature—A measure of the thermal energy in matter. Thermal energy is the kinetic energy of the random motion of the particles in an object.
- Precipitation/clouds—The movement of evaporated water, moisture in the air (water vapor).

In Lesson 1, students agreed that when talking about weather, *temperature* refers to the measure of the thermal energy of air—the relative warmness or coolness of the air. In this activity, they will focus on the condition of temperature. Where does the thermal energy come from?

Materials – Activity 2.1

For Each Student
- Activity Sheet 2.1

Activity 2.1 – It Is Heating Up

Students should refer to the idea that all energy is being transferred.

By tracing the matter and energy, students decided in Lesson 1 to try to figure out how storms are created. Discuss with students what they know about energy.

Students should refer to the idea that all energy is being transferred.

- Where does the energy come from?
- When you talked about temperature, what was heating up and cooling off? (*air*)

Discuss with students what they have learned about what happens when an object (matter, like air) gets hotter.

- What makes up all matter? (*All matter is made up of particles called molecules.*)
- What happens to the molecules when an object gets hotter? (*The molecules in an object are constantly moving and bouncing into each other. When they are heated, they move around faster and bounce off each other more. This movement is called kinetic energy.*)

The kinetic energy due to molecular motion is called thermal energy. Temperature is an indication of this energy.

- Where does the energy come from to heat the Earth? (*from the sun as solar or light energy*)
- What do you know about light energy that makes you think that?

Discuss the following ideas with students. If they have done the IQWST PS2 unit, examples from that unit are in parentheses following the idea. Otherwise, use whatever examples are familiar to students.

- The sun emits light (solar energy).
- Light is the source of energy. (Solar energy can be used to heat water. Students observed this when they heated beakers with dark and clear water and observed the temperature increases. They read about solar energy being used to heat water.)
- Light can be reflected, transmitted, or absorbed. (Heating the beakers with dark and clear water showed reflection, transmission, and absorption, but at different proportions.)
- When light energy is absorbed, it can be converted to thermal energy. (Temperature of the water increased when it absorbs the light energy. An increase in the temperature of an object, in this case the water, is an indication of an increase in the object's thermal energy.)
- What absorbs the solar energy that reaches the Earth? (Students should understand that much of the solar energy is absorbed by the Earth's surface.)

Review temperature-related questions on the DQB, and probe student understanding with questions such as:

- If temperature is the measure of thermal energy of air (atmosphere), how does air get heated? In what ways could the atmosphere be heated? (*Students will most likely think that the solar energy emitted from the sun is responsible for heating the atmosphere. They may think that the air absorbs the solar energy.*)
- Do you have any idea why temperature changes in one location or from one day to another? (*Students may demonstrate some understanding that air masses can move or some variables that affect the amount of thermal energy in an air mass can change. If not, prompt them to this understanding. Make it clear that the variables that affect air mass do not include day/night.*)
- What may happen to molecules in an air mass if the temperature changes? (*They can become more or less energetic.*)

- If the molecules have more energy, what happens to the temperature? If the molecules have less energy, what happens to the temperature? (*When the air molecules had more energy, the temperature increased; when the air molecules had less energy, the temperature decreased.*)

Make sure that students understand the difference between the movement of the object (air mass) and the movement of its particles. Ask students to explain the difference between the object getting hotter and the object moving. Both involve energy, but how are they different? Students should refer to the difference between the object moving and its particles moving. The particles in an object are always moving, and they move faster when the object is heated. This increases the kinetic energy of the particles. The more kinetic energy the particles have, the more thermal energy the object has.

If students have worked in the IQWST PS2 unit, ask them about the example of children on a bus. They can refer to the children moving around, bumping into each other when they are on the bus. This is the kinetic energy of the particles (children) and the thermal energy of the bus. If the bus starts to move, all of the individual particles (children) that are moving now move together as one unit. Therefore, the kinetic energy of the moving bus also increases.

- A large body of air collected in one location that has similar temperature (thermal energy) and moisture properties is called an *air mass*.
- Students may demonstrate some understanding that air masses can move, or that some variables that affect the amount of thermal energy in an air mass can change. This is an important concept and should be emphasized.
- The temperature of an air mass can change because the kinetic energy of the molecules increases or decreases.
- Somehow an air mass can move.

At the beginning of this discussion, students were asked to think about how air is heated. They agreed on the following ideas:

- The sun emits solar energy.
- Light is the source of energy in objects (matter).
- Light can be reflected, transmitted, or absorbed.
- Solar energy can be converted to thermal energy when absorbed.
- Light can heat things up.

Do these ideas help explain how air is heated? Ask students what tool(s) they have used previously to understand what is happening with something they can observe directly. If students have done the IQWST PS1 unit, they constructed a model of how they see. In the IQWST IC1 unit, they constructed a model of the particulate nature of matter. In this activity, students will construct a model of how the Earth's air is heated.

Creating a Model of How Air Is Heated

Using Activity Sheet 2.1, students will engage in an activity to construct the model. Explain to students that, based on what they understand about matter and energy and how matter can be heated, they are to work in a group to construct a model showing how air is heated. Their model needs to show the following:

- energy source
- matter that is being heated
- processes that are occurring (e.g., absorption, conversion)
- arrows showing the transfer of energy

After the models are completed, groups will share them. Possible models that may emerge are the following:

1. Air—The air absorbs the solar energy and converts it to thermal energy.
2. Ground—Objects on the Earth's surface absorb most of the solar energy and convert it to thermal energy. This does not explain how the air is heated.
3. Both—The objects on the Earth's surface and the air absorb the solar energy and convert it to thermal energy.

Use several models from the students' groups to begin to develop a consensus model of how air is heated.

Developing a Consensus Model

Review concepts from group models. The symbols <…> indicate possible concepts from students' models.

<The sun emits solar energy.> If students completed the IQWST PS2 unit, they learned that light energy coming from the sun is called *solar energy*. This is a concept that they should understand.

<Solar energy heats the surface.> Students should give examples from personal experience that solar energy can heat things.

- If I am out in the sun, my skin begins to feel warm.
- When I go barefoot in the summer, the sand (or cement) is warm.
- If I leave my bike in the sun, the handlebars get hot.

Students should be able to state that the sun heats all matter on the Earth's surface, because it is absorbed and converted into thermal energy.

Remind students that the purpose of their model is to explain how the air is heated. Help students understand that the solid and liquid objects on the Earth's surface absorb most of the solar energy. Discuss with students what they know about light being transmitted. If they completed the IQWST PS2 unit, remind them that when they heated the dark water, it got hotter than the clear water.

- What happened to the light in the clear water? (*Most of it was transmitted because the water was clear.*)
- What happened to the light in the dark water? (*Most of it was absorbed and the temperature went up.)*
- Is the air more like the clear water or the dark water? Do you think the solar energy is absorbed or transmitted by the air? (*The air is clear like the clear water, so it seems that most of the solar energy would be transmitted.*)

Have students copy the class model on their activity sheets and answer the Making Sense questions.

Ask students if the model answers the question of how the Earth's air is heated.

- Is there anything missing from our model?

- If the air transmits most of the solar energy it receives, how does the air get heated? Prompt students to think about how the thermal energy is transferred to the air.
- Where is most of the thermal energy absorbed? (*It is absorbed by the surface of the Earth*.)
- Does our model explain how the thermal energy from the surface gets into the air? What do you think happens? (*Students may know from IQWST PS2 that energy can be transferred, but they have not learned yet about the kind of transfer [conduction] that happens here*.)

In the next activity, students will try to answer the question of how the thermal energy from the Earth's surface gets into the air.

Materials – Activity 2.2

For Each Group (either class demonstration or group activity)

- (1) ring stand
- (1) metal bar
- (1) ring stand clasp
- (1) hot plate or stubby candle
- (4) pea-sized solid vegetable shortening balls
- paper towels*
- (1) paper plate*

For Each Student

- Activity Sheet 2.1
- Activity Sheet 2.2

*This item is not included in the kit.

Activity 2.2 – A Little Heat from Me to You

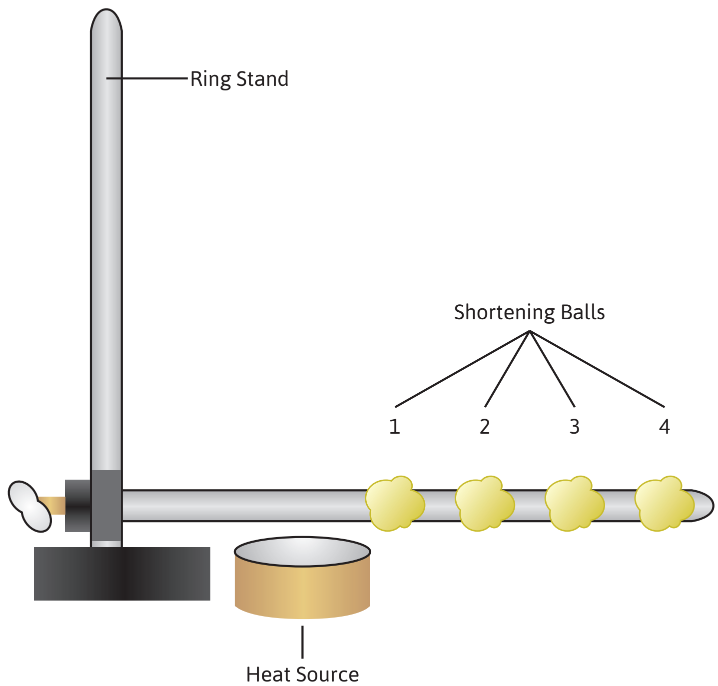
Investigating Heat Transfer

Students left Activity 2.1 with a question about how thermal energy is transferred from the Earth's surface to the air. Ask: "What examples can you think of in which thermal energy is transferred between objects?" Prompt students with an example to begin, if needed.

- a spoon that gets hot when you put it into a cup of hot chocolate
- your hand touching the outside of a cup that had hot water inside
- your finger touching a hot iron that burns your finger

Dividing students into small groups (of two or three) for this activity works best. However, depending on the materials available, this activity can be done by larger groups or as a demonstration for the whole class.

Students should set up the activity according to the directions on Activity Sheet 2.2. The setup should be similar to the following diagram.



Procedure for Setting Up the Apparatus

- A metal rod is placed perpendicular to the ring stand bar so that it is touching the heat source. (Do not turn on the heat source until the setup is complete.) The heat source can be either a hot plate or a short, stubby candle. Be sure that the crossbar is touching the heat source.
- Place a paper towel under the shortening balls, but away from the candle.
- Soften and shape the solid shortening into four pea-sized balls.
- Press the balls on the crossbar at equal intervals beginning at the end opposite the heat source.

After students record and explain predictions, they should complete the investigation using Activity Sheet 2.2.

Discussion – Making Sense

Purpose

To define the process of conduction.

Have students share the results of the activity and gauge how it compared to their predictions. Engage students in a Sense Making discussion in order to answer the question from Activity 2.1: How does the thermal energy get from the surface to the air?

- What were the results of this experiment?
- What happened to the balls of shortening? (*They fell off of the rod but at different times.*)
- Was there any pattern to the way they fell off? (*The ones that were closest to the heat source fell off first.*)
- Where did the heat come from? (*The hot plate/candle*)
- Were the shortening balls over the heat source? (*No, they were away from the heat source.*)
- Why do you think the shortening melted? (*The rod got hot and melted the shortening.)*
- Why did all of the shortening melt at the same time?
- What does this tell you about what was happening to the rod? (*Students should be able to say that the entire rod did not get hot at the same time.*)
- Do you think the thermal energy from the hot plate was being converted or transferred along the rod?
- What makes the rod warmer?

Press students to arrive at the molecular explanation of what is happening. (*The molecules in the rod are moving faster over the heat source and have more kinetic energy. They have more thermal energy.*)

- How was the thermal energy transferred along the rod? (*Help students to understand that the faster moving molecules in the rod bumped into the slower moving molecules. Some energy was transferred to the slower moving molecules, causing them to move faster and increase the thermal energy along the rod.*)
- Was anything else being heated besides the rod? How do you know? (*The shortening was also being heated because it melted, and shortening melts when it gets hot, so thermal energy was being transferred from the rod to the shortening.*)

- The transfer of energy through an object to another is called *conduction*.
- For conduction to occur, two objects (matter) must be in contact with each other. In this activity, the shortening balls were in contact with the metal rod.
- Conduction can occur within an object (like the metal rod) or between objects (the shortening and the rod). An example of within-object conduction is the heating of the rod. As the molecules at one end of the rod were heated, their motion increased. This caused them to bump into the molecules that were next to them and transfer energy to them. This continued until the motion of the molecules (kinetic energy) raised the temperature (thermal energy) of the rod.

Ask students how this experiment can help them explain how the air at the Earth's surface can be heated. (*Solar energy from the sun is absorbed mostly by the Earth's surface and converted to thermal energy. The air comes in contact with the Earth's surface. Thermal energy is transferred to the air by conduction. The air is heated by the Earth's surface causing the molecules in the air to move faster (more kinetic energy). This increases the temperature of the air. As the molecules in the Earth's surface continue to absorb solar energy, they continue to transfer thermal energy to the molecules around them and increase the thermal energy of the air.*)

Discuss the idea of a scientific principle. If students have done previous IQWST units, they are familiar with this idea. When scientists come to a common understanding about things, they call those ideas *scientific principles*. Students have just developed two principles about how air at the Earth's surface is heated.

Does everyone agree with the following statements?

- Light energy from the sun is mostly transmitted through the air before reaching the Earth's surface and that surface absorbs some of the light energy that reaches it.
- Molecules transfer thermal energy from one end of an object to another and to other objects by collision between molecules that transfer the kinetic energy of one molecule to another (*conduction*).
- The air at the Earth's surface is primarily heated by the transfer of thermal energy from the ground below it.

Does anyone disagree with these statements? Why? What evidence do we have that these principles are true?

Once students agree, create a Scientific Principles list and post it near the DQB. This will be used throughout the unit to keep track of the big ideas about matter and energy that students develop.

Return to the DQB and the Matter and Energy chart. What can we add to our chart?

In the Temperature row of the Matter column, add the following:

Remind students to add these ideas to their Driving Question Notes.

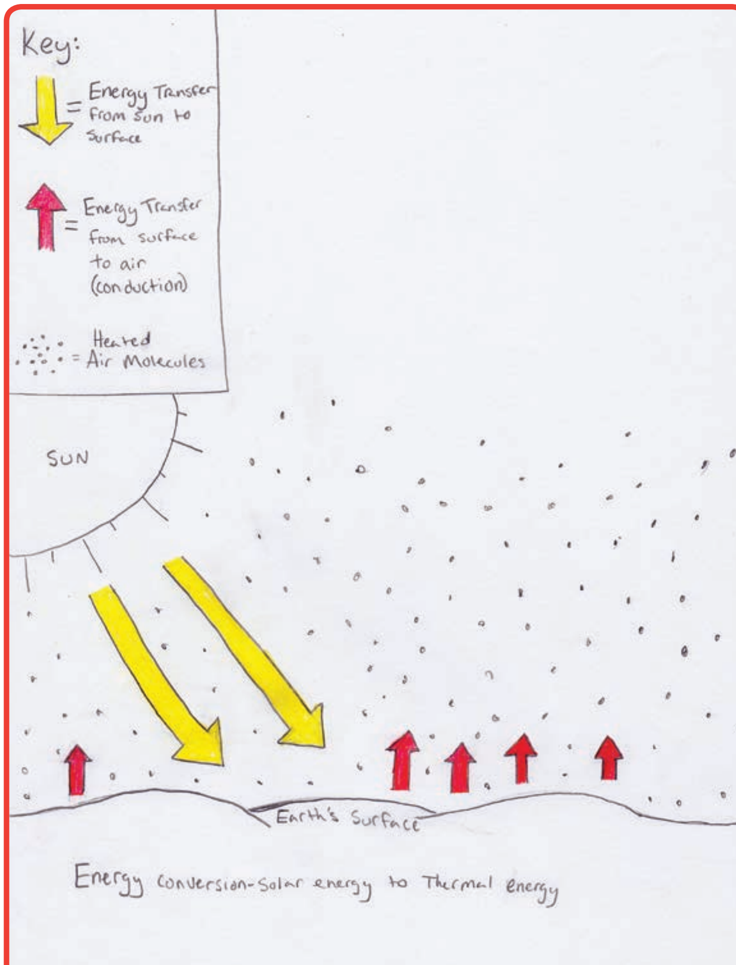
Wrapping Up the Lesson

- What do we still need to learn?
- How is thermal energy transferred in the air?

Return to the class model of how the air is heated, and ask if there is anything that can be added to the model. Students should now be able to label the transfer of thermal energy from the surface to the air as conduction. The class model should include the following points:

- the sun
- the Earth's atmosphere (molecules)
- labeled energy transfers and conversions

Post a copy of the consensus model of how air is heated on the DQB. We still do not know how the heated air at the surface rises to higher levels in the atmosphere or how this might contribute to a storm forming. In the next lesson, students will explore how thermal energy is transferred in the air.



Sample Consensus Model

Introducing Reading 2.2 – Why Does Conduction Matter?

This reading connects students' everyday experiences to what they have learned about the phenomenon of conduction. Use the Getting Ready question to have students begin to think about how food gets hot. Prompt them to think about what is happening with the energy when food heats.

Lesson 3

What Happens to the Hot Air?

PREPARATION

Teacher Background Knowledge

See Unit Overview for general background knowledge for this unit.

Setup

Introducing the Lesson

Before students enter the room, set up a lamp without a shade and an incandescent bulb. The light should be burning long enough to feel the heat from the bulb.

Activity 3.1

Heating water before class is recommended. Use a tea-kettle-type container so that you can distribute the hot water to each of the groups.

Activity 3.2

Students need ice water for this experiment. It is fine if the ice melts before the students use the water, as long as the water remains very cold.

Safety Guidelines

- Use safety goggles during Activities 3.1 and 3.2.
- In Activity 3.1, handle matches and the lit incense carefully. Do not walk around with them lit.
- The teacher should prepare and distribute the hot water, cautioning students not to move near it.
- Activity 3.2: Balloons are used in this activity. Be aware of any students with latex allergies.
- You will burn incense in this activity. Students with asthma or other breathing difficulties may need to sit closer to a window or other ventilation, or you may need to make other accommodations.

Differentiation Opportunities

1. If students are not able to complete both trials in one class period, a second day may be needed. Be sure to have the hot soil and ice water ready before class.
2. The introduction to the lesson along with the introduction to the activity could be completed on Day 1, and then the actual experiment could be completed on Day 2.

Lesson 3

What Happens to the Hot Air?

TEACHING THE LESSON

Performance Expectations

Students will

- analyze results from a physical model to explain why hot air rises and cold air sinks.
- construct and defend a model of convection that explains why hot air rises and cold air sinks in terms of movement of air masses due to density differences.
- analyze the differences between conduction and convection in terms of energy transfer and flow of matter.
- apply a model of convection to explain one cause of wind.

Building Coherence

The purpose of this lesson is to figure out what happens to the hot air once it is heated at the surface. Students will be introduced to the concept of convection as a mechanism for the movement of both matter and energy. This lesson builds on concepts from other IQWST units [IC1, IC2, and PS2] including the particle model of matter, density, and energy transfer.

Timeframe

3 Class Periods

Overview

Activity 3.1

Investigate changes in density due to the heating and cooling of gases. Use a convection box to observe what happens to the air (smoke) when part of the box is heated and there is cooler air on the other side.

Activity 3.2

Use a physical model to determine why the warmer air rises.

Activity 3.3

- Create a consensus model of convection using the principles of convection and density.
- Create a model of how the air moves in the atmosphere.

Materials – Introduction

For the Class

- (1) lamp with a 100- or 150-watt incandescent bulb (no lamp shade)

Introducing the Lesson

Set up lamp described in Lesson Preparation. Have the lamp turned on so that the bulb can heat. Students completed Lesson 2 with a model that showed that air is heated by conduction from below. They were left with the question of what happens to the hot air. They will investigate that question in this lesson. Ask a student to come up and hold his or her hand next to the bulb and then above the bulb. The hand should be held approximately the same distance from the bulb both times.

Be sure to try this before class, in order to determine the distance students need to hold their hand from the lamp to experience the phenomenon. Students should be able to feel more heat above the lamp than next to it.

Suggested Prompts

- Do you feel the same amount of heat everywhere?
- Is it hotter some places than others?
- Can you explain what is happening to the energy here?
- In the last lesson, what did you learn about how air is heated? (*Air is heated by conduction.*)

Return to the DQB and remind students that they are trying to figure out why the weather is not the same from day to day. In the weather data from their cities, they have seen that the temperature changes from day to day, but they do not know why.

Ask students the following questions:

- What do you think would happen if a mass of cold air and hot air were next to each other? (*Based on what students learned about conduction, they might suggest that the hot air will transfer [conduct] thermal energy to the colder air.*)
- How could you investigate this question?
- What problems might you have in figuring out what is happening with the air? (*The idea that air is not visible should come up here. They should also suggest that there is a lot of air outside and that it would be very difficult to observe what is going on in large air masses.*)

In the next activity, students will use a physical model in order to see what happens when colder air comes in contact with warmer air. This model will allow them to control the temperature of the air and observe the effects of temperature differences.

Materials – Activity 3.1

For Each Group
- (1) convection box
- matches*
- incense
- (2) Petri dishes
- soil that includes a variety of gravel* (the gravel will help retain the heat longer)

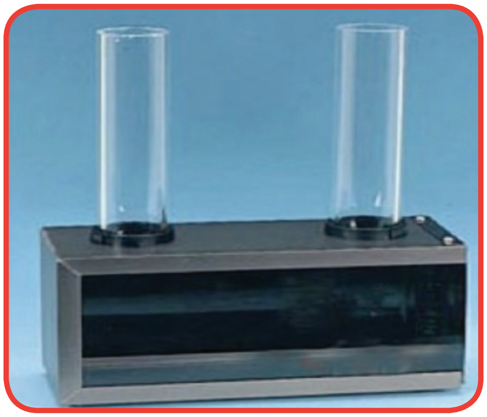
For Each Student
- (1) pair of safety goggles*
- Activity Sheet 3.1

*This item is not included in the kit.

Activity 3.1 – How Do Differences in Temperature Affect Air Masses?

Using the Convection Box

In this activity, students will use a convection box (see picture) in order to investigate what happens when cooler and warmer air come together.



The term *convection* should not be introduced at this point. Simply refer to the box as the apparatus used in the experiment. The phenomenon of convection will be labeled after students have seen evidence of it.

Be sure to try this before class in order to determine the distance students need to hold their hands from the lamp to experience the phenomenon. Students should be able to feel more heat above the lamp than next to it.

Since air is not visible, students will create smoke using incense in order to observe what happens. The smoke moves as part of the air and allows students to see how the air is moving.

If students have done either the IQWST IC1 unit or the IQWST LS1 unit, they may suggest that the incense is like the indicators that they used in those units. In Chemistry, they used an indicator paper to show the presence of ammonia in the air, and in Life Science, they used an indicator (iodine) to show when starch was present. Both of these indicators allowed students to see something that they could not see directly.

Without actually using the hot soil and smoking incense, demonstrate for them how the experiment is to be done. On Activity Sheet 3.1, have students predict what they think will happen during the experiment. They should predict what will happen if the incense is held over the tube above the cold water and then what will happen if it is held over the tube above the hot soil. Once they have made their predictions, have them conduct the experiment in their groups.

Students should follow the instructions on Activity Sheet 3.1 for completing Trial 1. They should complete their diagram and description of what happened. Be sure to check that students have set up the apparatus correctly before they begin. When Trial 1 is complete, groups should proceed to do Trial 2. Before they begin Trial 2, the teacher should check to be sure that the soil is hot enough. When Trial 2 is finished, they should complete the activity sheet. After cleaning their work area, have students answer the Making Sense questions on their activity sheet.

Sharing Ideas

Suggested Prompts

- Ask one group to describe what happened to the smoke in the box in Trial 1. (*The smoke went down the chimney over the cold water and moved across the box and up the chimney over the hot soil. The warmer air rose.*)
- Did everyone get the same results? If not, what was different?
- How does what happened compare with your prediction?
- Did you get the same results in Trial 2? (*Students should indicate that in Trial 2, the smoke from the incense was not pulled into the box. If all groups did not get the same results, you may want to repeat the experiment as a demonstration. Students should all see the same thing happening to the smoke in the box.*)
- What do you think happened? Why did the smoke move the way it did? (*Students should reach the conclusion that the hotter air and colder air behaved differently. The hotter air rose, but the cooler air did not.*)
- Why do you think the hotter air rises? (*At this point, this remains an open question and should be posted on the DQB.*)

In this activity, they observed what happened when air masses of different temperature came in contact. In the next activity, students will investigate what happens to a single air mass when it is heated and cooled.

Homework

Using what students understand about convection and the model of the experiment they created, they are asked to show how convection happens in a room by explaining what is happening to the matter and energy. Students first use arrows to show the movement of air and then use energy transfer and conversion to explain what is happening.

Materials – Activity 3.2

For Each Group

- (1) empty, dry plastic drink bottle*
- (1) small balloon that can be stretched over the mouth of the bottle
- (2) containers deep enough to submerge the bottle in water halfway up
- (1) balance or scale
- tongs

For Each Student

- (1) pair of safety goggles*
- Activity Sheet 3.2

*This item is not included in the kit.

Activity 3.2 – What Happens When Air Is Heated or Cooled?

Homework Follow Up

Have students share their diagrams and explanations of convection.

Setting Up the Investigation

In the last experiment, what happened to the heated air? It rose up and out of the box. If you want to figure out why heated air rises, what would you need to change about the last experiment? Guide students to the following ideas:

- Only hot air is needed in order to figure out what is happening to it.
- In the last experiment, the hot air left the convection box. We would need some way to trap the air. We want to trap the hot air to see what happens and then cool it to see if there are any changes.

Ask: "What do you know about air?" Students should come up with the following ideas:

- Matter is anything that has both volume and mass.
- Matter is made of molecules. (In IQWST IC1, students created a particle model of matter.)
- Molecules are always in motion.
- Air has mass and volume and is matter.

Show students the materials (bottle, balloon, and rubber band) that they will use in this experiment. Use the following prompts to get students to think about what they need to use and observe.

Suggested Prompts

- What do you think the balloon could be used for in the experiment? (*The air needs to be kept in the bottle, so the balloon can be used to seal the bottle*.) You may want to demonstrate this for students.
- What could we do to figure out if there were changes in the bottle? (*Remind students that they said air is matter and that matter has volume and mass.)*
- What could you observe or measure about the bottle, air, and balloon that might help you figure out if the air inside the bottle changes when it is heated? (*This question is meant to get to the items in the Prediction section of the activity sheet. Based on what they know about air, students should suggest that they could measure the mass of the bottle, air, and balloon before and after they are heated*.)
- Why would you want to measure it both before and after?

Discuss the idea of a closed system with students. If they are not familiar with the concept, it is important to explain it to them. If students did the IQWST IC2 unit, they learned that mass is conserved in a closed system. (*If the mass of the bottle, and so on, remained the same, then they know that nothing escaped from the bottle*.)

- What do you think would happen if we released the hotter air into the lower temperature surrounding air? What would it do? (*It would rise because it is less dense*.)

Bottle and Balloon Investigation

Using Activity Sheet 3.2, students should read the purpose of the activity, in addition to the paragraph at the top of the page that further explains what they are going to do. Explain that the word *system*, in this experiment, refers to the bottle, balloon, rubber band, and air in the bottle.

Have students make predictions and complete the activity. Remind students that they are trying to figure out what happens to the matter and energy in a storm. Understanding how air behaves when heated and cooled will help them answer that question.

Sharing Observations

When students have finished, have them share their models of what they observed. Their models should show the following observations:

- When the system is heated, the warmer air in the bottle expands into the balloon. The model should show molecules farther apart, and arrows should indicate upward movement.
- When the system is cooled, the molecules should be close together, and arrows should indicate downward movement.

Use the following prompts with students for creating a consensus model of what they observed.

- What happened to mass in this investigation? (*Mass should not have changed from before heating to after heating.*)
- What happened to volume? (*No air was added to the bottle, but the balloon inflated. This showed that the air was taking up more space—increasing the volume.*)

Ask: "What do you know about density?" If students worked with the IQWST IC1 unit, they learned that density is the relationship between mass and volume.

- When matter is heated, it becomes less dense. The volume increases and there are fewer molecules in the same amount of space.
- When matter is cooled, it becomes denser. The molecules are closer together and take up less space.
- There are more molecules in the same amount of space.
- Is hot air more or less dense than cold air? Why? (*It is less dense because the molecules are moving faster [transfer of thermal energy] and are farther apart.*)
- Does the experiment show that the hotter, less dense air is expanding? (*The balloon on top of the bottle inflated. This means that the heated air in the bottle is expanding.*)
- What happens to the air molecules in the bottle when they are cooled? How do you know? (*They become denser because the molecules move less and are closer together. They collapse back into the bottle.*)

Students have created models of the movement of matter and energy in two situations. In the next activity, they will combine these models to explain why heated air rises.

Materials – Activity 3.3

For Each Student

- Activity Sheet 3.3
- Reading 3.3

Activity 3.3 – Why Heat Rises

Creating Group Models

In the first activity in this lesson, students saw smoke (air) rising in the convection box over the heat source. Then, they created a model of what happened. Next, they observed that temperature can cause differences in density and cause air to rise or sink. Then, they created a second model. In this activity, students will combine their models in order to develop a consensus model of why hot air rises.

Refer to the DQB and remind students that they are trying to figure out what happens to matter and energy as they relate to weather conditions, particularly in a storm.

Use the following prompts to help students develop a list of things to include in their model.

- What were the important elements in the experiments you just did?
- What was the effect of temperature differences?

Emphasize that it was the air that was moving in both experiments. In the convection box, the smoke helped them to see the moving air. In the second activity, they saw the air expand in the bottle into the balloon.

- Where did the matter go?
- What was happening to the molecules in the air?
- Where did the energy go? How was the energy transferred? (*In the convection box, energy was transferred by conduction from the heat source to the air. Matter and energy were moved by convection because the heated air became less dense and rose. In the bottle and balloon, energy was transferred by conduction from the heated water to the bottle. The bottle transferred energy to the air. The air became less dense and expanded and rose into the balloon.*)

Using Activity Sheet 3.3, review with students the items that need to be included in their model:

- location of the heat source
- a label to show how the air is heated (energy transfer by conduction)
- location of hotter and cooler air masses
- arrangement of molecules in each of the air masses
- small arrows showing the movement of molecules within each air mass (representing the kinetic energy of the air mass)
- large arrows showing how each mass of air is moving

Allow groups time to complete their models and write a description of what is happening.

Discussion – Synthesizing

Purpose

Reach consensus on why hot air rises (conduction and convection model).

Bring the class together and have one group share their model with the class using the board. Compare the model to the previous bullet points. During the discussion, the class may suggest changes to the model the group has shared. The change should be made to the class model if most students agree.

- What does this model show?
- Does it include all of the parts?
- Do you agree with how the molecules are represented? What would you change? (*Students should know that during heating, molecules move faster*

and spread out if they can. This concept is covered in the IQWST PS2 unit.)

- Does the model show how the air is heated?
- Do you agree with how the air masses are moving?
- What do you know about the molecules in a cooler air mass? (*They are closer together than in a warmer air mass.*)
- Does this model show a difference in the arrangement of molecules in the hotter and cooler air masses? If not, how should the model be changed to show this?
- Does the model show how the air masses moved? If so, how? (*The model should show the hotter mass rising and the cooler one moving in to take its place.*)
- How should the model be changed to show this?
- Did the heated air move the same way in the bottle? (*The hotter air moved up and into the balloon, but once all the air was heated, there was no cooler air to move in to take its place. It was also different from the convection box, because there was not a constant heat source.*)
- Is there a heat source in the diagram?
- Why is the heat source important? (*If there was no heat source, there would not be a temperature difference. The temperature difference occurs because energy is transferred from the heat source to the air. That causes the molecules in the air above it to move faster and increase its thermal energy.*)
- How is energy transferred from the heat source to the air?

In Lesson 2, students learned that energy is transferred from the Earth's surface to the air by conduction. In the model, the energy is transferred from the heat source to the air in the same way. If conduction is not on the model, add it now.

- How was energy transferred in the bottle experiment? (*Energy was conducted from the hot water to the bottle to the air inside the bottle by conduction.*)

Add to Scientific Principles list statements such as the following: "Differences in temperature can cause air to move." This idea should also be added to the DQB in the Matter column of the Temperature row. In the Energy column, add the following information: "Energy is being transferred from the heat source to the air, increasing the kinetic energy of the molecules. This is conduction. The hotter air becomes less dense and rises and transfers energy to the air above. As it rises, cooler air moves in to take its place. Energy is transferred by the movement of the air mass. This is convection."

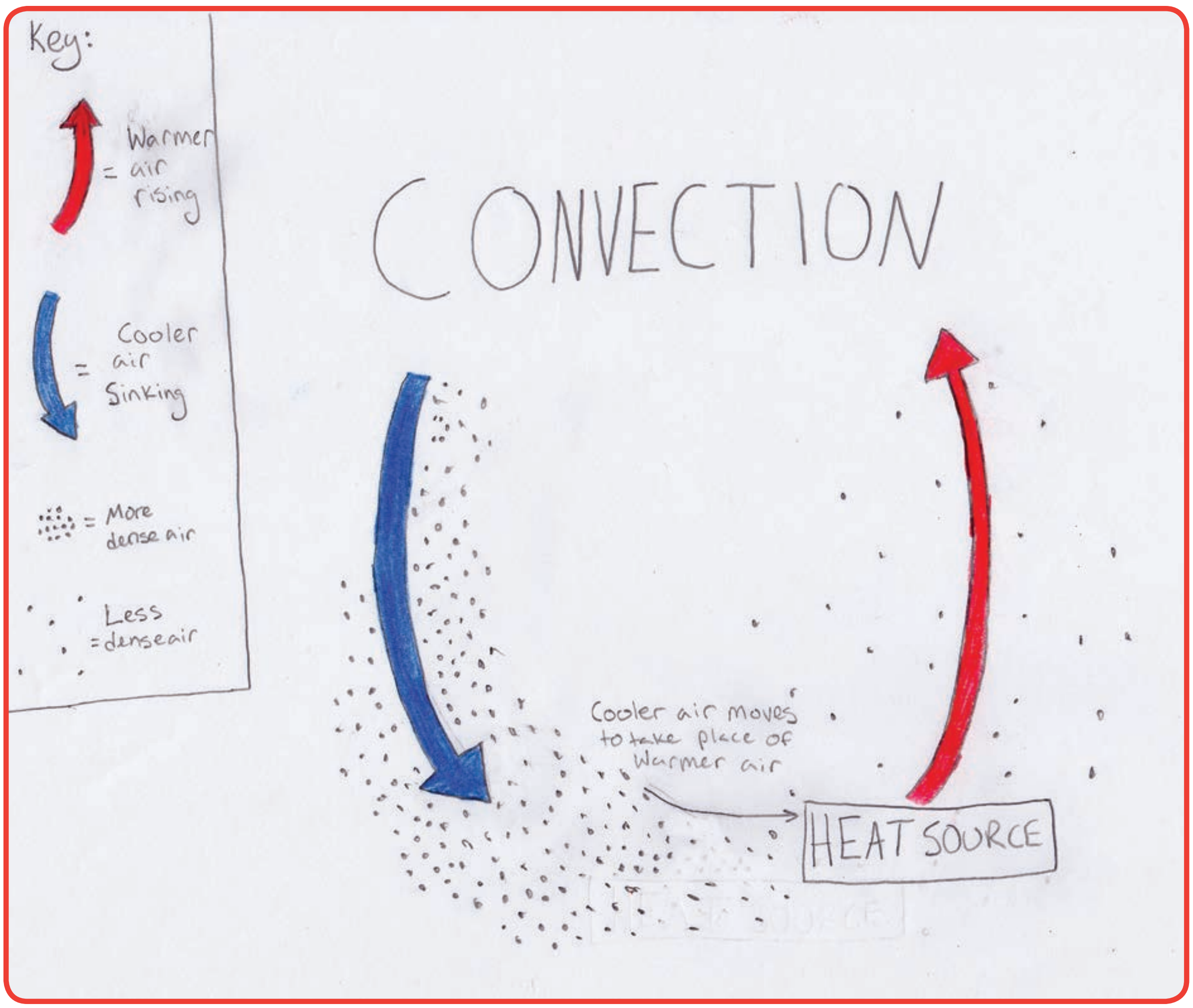
If students have completed the IQWST PS2 unit, ask them about the example of kids on a bus. They can refer to the kids moving around and bumping into each other when they are on the bus. This is the kinetic energy of the particles (kids) and the thermal energy of the bus. If the bus starts to move, all the individual particles (kids) that are moving move together as one unit. Then the kinetic energy of the moving bus is also increasing.

Both of these words *conduction* and *convection* should be added to the consensus model. The class model should be similar to the following one but should reflect students' suggestions and ideas. Allow students a few minutes to copy the class consensus model onto Activity Sheet 3.3.

Sample Convection Model

At the end of Activity Sheet 3.3 is a question about the light bulb. Ask students if they can use the consensus model of convection to explain what happened.

Using the Making Sense Question
The Making Sense question about the light bulb can also be assigned as homework and followed up on at the beginning of the next lesson. It is a good assessment of student understanding of conduction, convection, and moving air.



Discussion – Synthesizing

Purpose

Synthesize ideas about conduction and convection and apply the consensus model to what happens in the atmosphere.

Suggested Prompts

- Do you think that this model of convection can help us explain what happens in the atmosphere?
- How do you think what happens in the atmosphere would be similar? Different?

Remind students that they are trying to figure out what happens to weather conditions to create a storm.

- How would understanding how air moves in the atmosphere help explain a storm?
- Since you already have a model of convection, do you think you can take that model and create a model of what happens in the atmosphere?

On the board or on paper to project with a document camera, create a model of how air in the atmosphere moves using the principles of conduction and convection. Remind students that in this model, they are talking about large air masses.

In Lesson 2, they learned that a large parcel of air that that has the similar properties throughout is called an *air mass*.

Suggested Prompts

- What do you need to make convection happen? (*You need a heat source.*)
- How is air above the Earth heated? *(It is heated from below by conduction.*)
- What is the heat source in your model? (*The Earth is the heat source.*)
- How is this heat source different from the convection box? (*This heat source is not constant; it changes.*)
- What happens to the air as it is heated according to your model of convection? (*The thermal energy from the Earth is transferred to the air. The air molecules move faster and farther apart. They become less dense than the air around them and rise.*)
- What label on the model should show transfer of thermal energy from Earth to air? (*The label should be conduction.*)
- How would you arrange the molecules of air? (*They should be farther apart than the surrounding air [less dense].*)
- What label on the model should show the molecules of heated air rising? (*The label should be convection.*)
- What happens to the air as it cools? (*The air has less thermal energy. Molecules of the air are closer together—denser. More molecules are closer to Earth.*)
- What happens in the space left by the rising, less dense air? (*Cooler, more dense air moves in to fill in the space left by the rising air.*)
- What do you call moving air? (*Moving air is called wind.*)
- What created the wind in your model? (*The temperature/density differences between cooler and warmer air caused convection.)*

Ask students the following questions:

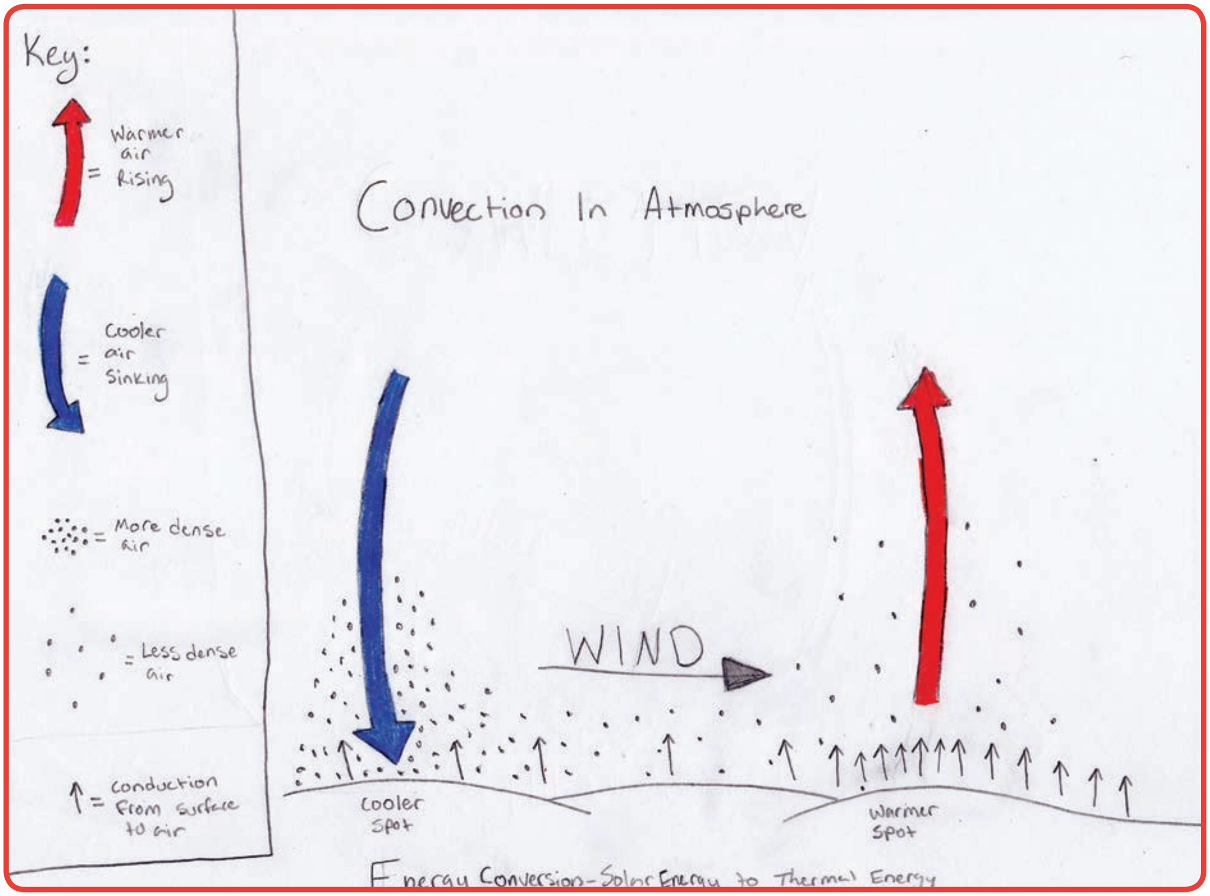
- Does anyone want to add anything else to the model?
- If not, can we agree that this is how we think air moves in the atmosphere based on what we understand about convection?
- Are there questions about how air moves in the atmosphere that you still have? If so, add these to the DQB.

Once the class agrees on the model of how air moves in the atmosphere, post it on the DQB. See the following sample model.

Convection in the Atmosphere

Return to the list of Scientific Principles and add the following items.

- Differences in temperature can cause air to move. This movement is called *convection*.
- Thermal energy is transferred by the movement of matter.
- What does this lesson have to do with weather?



Wrapping Up the Lesson

Both wind and temperature are on the DQB as weather conditions that are important in a storm. Ask students if what they have learned in this lesson is enough information for them to explain what happens to cause a storm.

- What do we still need to learn?
    - o Do any of the other conditions we saw in the weather data contribute to a storm?

Add any new questions to the DQB.

In the next lesson, students will investigate other factors (pressure, humidity, and lift) in order to develop a storm model.

Introducing Reading 3.3 – Why Learn about Convection?

Ask students if they have ever roasted marshmallows over a fire or grill. Use the Getting Ready question to have them think about how the marshmallows cook if they are not in the fire. This reading focuses on common, everyday examples of convection.

LESSON 4

Where Does the Energy Come from in a Storm?

PREPARATION

Teacher Background Knowledge

Barometers

- Changes in air pressure are indications of changes in weather. This change is measured using a device called a *barometer*. The first barometer was created in 1643 by Evangelista Torricelli using mercury in a tube that was inverted into a bowl of mercury. He observed that the top of the mercury in the tube fluctuated by a few percent, due mainly to what we know now to be changes in air pressure. This is because the column of air directly above the setup pushes on the dish containing the mercury. This forces the mercury up the tube. The higher the pressure, the higher the mercury rises. This is where the unit, inches of mercury, is derived. Air pressure in weather reports is often reported using this measurement.
- In this activity, students will construct a water barometer, also known as a storm glass. These types of barometers have been around since the 17th century. The actual change of pressure in this device occurs too slowly for direct observation. However, over a 24-hour period, the change will be noticeable.

Fronts

- In this unit, students primarily study cold fronts where cooler air is replacing warmer air because it is along cold fronts that storms most often occur. Fronts are the leading edges of air masses.
  - o Warm front—This front occurs when a warmer air mass replaces a cooler air mass. Generally, a warm front moves from southwest to northeast. Weather behind the front becomes warmer and more humid.
  - o Cold front—This front occurs when a cooler air mass replaces a warmer air mass. Clouds and precipitation often occur at a cold front because the warmer air rises, cools, and condenses. The weather behind a cold front is cooler and drier.
- Other front types include two types of occluded fronts (an occluded front is a formed boundary where frontal systems of large temperature differences collide):
  - o Cold occlusion—The air mass overtaking a warm front is cooler than the cool air ahead of the warm front, causing the mass to plow under both air masses.
  - o Warm occlusion—The air mass overtaking a warm front is not as cool as the cold air ahead of the warm front; therefore, it rides over the colder air mass while lifting the warm air.

Instability

- To understand stability/instability, you need to know that as air rises, it cools at a rate of 5.40°F for each 1,000 feet it rises. It cools at this rate as long as the humidity in the air is not condensing.
- The 5.40°F cooling rate is the same no matter how warm or cool the surrounding air is.
- Rising air cools at this regular rate because it is moving into lower pressure air, aloft and expanding. Expansion cools the air. (Sinking air warms at the same rate because it is being compressed as it descends.)
- Even though warm air rising from the surface cools, if it remains warmer than the surrounding air, it continues to rise. This rising air is said to be unstable.

Humidity

- The term *water vapor* rather than *water* should be used when referring to humidity. Water vapor is a gas that is lighter than oxygen and nitrogen. As a gas, the molecules are free to move about. Students should understand that water has three phases: solid, liquid, and gas (IQWST IC1).
- Unlike other gases in the atmosphere (~78% nitrogen, ~21% oxygen, ~1% trace gases) that remain constant, the amount of water vapor does not. All water vapor will convert back into the liquid phase through condensation and eventually leave the atmosphere.
- Humidity is the amount of water vapor in the air.

Setup

Activity 4.2

The demonstration in this activity requires practice.

Activity 4.2 is done twice. The first trial requires room temperature water. In the second trial, you will need warm and cold water. If the tap water available does not get hot, you will need to heat some before doing the activity. The water does not need to be boiling, but there should be a significant temperature difference between the warm and cold water in the second trial.

Procedure

Trial 1

1. Fill one beaker with room temperature water and add a few drops of red food coloring, so that the water is dark enough to clearly see the color. Do not make it so dark that students will not be able to see what is happening.
2. Fill a second container with room temperature water and use blue food coloring, stirring to distribute the color.
3. Make sure the cups you are using match up exactly in size. Place one on top of the other before filling to ensure that they match exactly.
4. Fill one cup with the red water until it is almost overflowing. Fill the second cup with blue water until it is almost overflowing.

5. Place the index card on top of the cup containing the red water. Press down on the top of the card to form a seal. Keeping your hand flat on the card, slowly turn the cup over above the container until it is upside down. Carefully take your hand away to make sure the seal is set. Then put your hand back on the index card.
6. Move the cup with the red water over the top of the cup with the blue water so that the edges match up and the card acts as a boundary between the two cups.
7. Once the two cards are stacked on top of each other, slowly remove the index card. Be sure to keep one hand on both cups, where the rims meet, in order to be sure they stay in place.

    - What happened when the index card was removed? (*The blue and the red water mixed together.*)
    - What do you think will happen if we turn the cups on their sides and the two masses of water are forced into each other? (*Student answers may vary. They may say the water will all mix together completely, the water will separate back to red and blue, or nothing will happen.*)

8. Keeping one hand on each cup, slowly turn the cups to one side while holding the middle together.

    Be careful to hold them together since they are not sealed.

    Note: You may want to put a thin strip of duct tape on two sides of the cup where they come together. This will not hold the cups together as you turn them, but it will make it easier to keep them lined up.

While you are preparing for Trial 2 of the demonstration, have students complete questions 1 and 2 for Trial 1 on their activity sheets. Then, have students predict what they think will happen in Trial 2 when one cup has cold water and the other has hot. Use the following procedure for Trial 2. Make sure there is a significant difference in temperature between the two cups of water, or you will not get the desired results.

Trial 2

1. Fill one beaker with hot water and add a few drops of red food coloring, so that the water is dark enough to clearly see the color. Do not make it so dark that students will not be able to see what is happening.
2. Fill a second container with cold water and use blue food coloring, stirring to distribute the color. Be sure that there is a significant temperature difference between the red and blue water.
3. Make sure the cups you are using match up exactly in size. Place one on top of the other before filling to ensure that they match exactly.
4. Fill one cup with the red water until it is almost overflowing. Fill the second cup with blue water until it is almost overflowing.
5. Place the index card on top of the cup containing the red water. Press down on the top of the card to form a seal. Keeping your hand flat on the card, slowly turn the cup over above the container until it is upside down. Carefully take your hand away to make sure the seal is set. Then put your hand back on the index card.
6. Move the cup with the red water over the top of the cup with the blue water so that the edges match up and the card acts as a boundary between the two cups.
7. Once the two cards are stacked on top of each other, slowly remove the index card. Be sure to keep one hand on both cups, where the rims meet, in order to be sure they stay in place.
8. Keeping one hand on each cup, slowly turn the cups to one side while holding the middle together.

Be careful to hold them together since they are not sealed.

Note: You may want to put a thin strip of duct tape on two sides of the cup where they come together. This will not hold the cups together as you turn them, but it will make it easier to keep them lined up.

Activity 4.3

You will need to access a storm video on the Internet. It should show a building, cumulonimbus cloud. Students should see the cloud building from the bottom up and spreading out. The video should enable students to answer the following:

- What happens to the shape of the cloud? (*Observations may include it gets bigger; it looks like clouds are forming inside of the bigger cloud; it is rising from the ground; and near the end, there are little clouds coming out of the top.*)
- What happens to the size and shape of the cloud? (*It gets wider and taller.*)
- Are all parts of the cloud behaving in the same way? Explain your answer. (*In some parts, there are smaller clouds forming. Some parts of the cloud are getting taller.*)

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

1. In Activity 4.1, data from the class barometer should be collected each day and recorded on the activity sheet. Actual pressure readings from the daily weather report should be recorded as well. The class will return to this activity in Lesson 5 to examine the data and develop a definition of air pressure.

2. Reading the water level of the barometer can be done by the students. Each group can be responsible for a day. Students should record the water level in the tube at approximately the same time each day (e.g., the beginning of class). They should record the information on the board (or class chart) so that everyone can copy it onto their activity sheets.

3. Recording the actual barometric pressure from the weather report can be done through the Internet or newspaper. Be sure to use the same source each time.

Lesson 4

Where Does the Energy Come from in a Storm?

TEACHING THE LESSON

Performance Expectations

Students will
- construct and defend an explanation for how the degree of temperature difference between two air masses affects air movement.
- revise their models of convective movement of air masses to explain the phenomena of lift and instability.
- revise their models of convective movement of air masses to explain the causes of energy flow, precipitation, and air movement in convective storms.

Building Coherence

Students investigate pressure as another weather condition and simulate the processes and interactions of the conditions that lead to a storm. In Lesson 3, students discovered that differences in temperature between two air masses can cause air to move and that this movement creates wind. They created a model of how energy moves in the atmosphere. In this lesson, they build on those ideas in order to create a model of a storm, which they will test against data in Lesson 5.

Timeframe

2–3 Class Periods

Overview

Activity 4.1
Construct a barometer to investigate the idea that air has pressure.

Activity 4.2
Observe a simulation using water (representing air) in order to develop the concept of a front and lift caused by density differences.

Activity 4.3
Add to the model they began in Lesson 3 to complete the model of what happens in a storm.

Introducing the Lesson

Students concluded Lesson 3 with a model of how air moves in the atmosphere via convection. Since they know that air moves, ask what else about air they need to understand in order to explain a storm.

Ask students the following questions:

- In your model, what caused the air to move? (*Temperature differences cause air to move.)*
- How were the molecules arranged in your model? (*The hotter molecules were farther apart; the cooler molecules were closer together.*)
- What does that tell you about the density of the hotter and cooler air? (*The cooler air is denser than the hotter air.*)

Based on the students' model, they should be able to link temperature differences with density differences. Use the DQB to remind students of the other conditions they identified from the weather data.

Suggested Prompts

- Do you think any of these other conditions could be related to density?
- Do you think pressure and density could be related? Why? Have students review what they know about density and pressure.
- What is the movement of molecules in an object? (*kinetic energy*)
- What is the total kinetic energy of all the molecules in an object? (*thermal energy*)
- How is thermal energy measured? (*by temperature*)
- If the same number of molecules is compressed into a smaller space, do the molecules become denser, and how does that affect temperature? (*Yes, it becomes denser. They are packed together more tightly and have less room to move. Therefore, less thermal energy equals lower temperature.*)

Students should understand that there seems to be a relationship between temperature and density, and that pressure can cause a change in density. Ask students if they think air has pressure.

Let students know that air pressure is difficult to understand, so they are going to use a setup in order to help them understand that air has pressure.

Materials – Activity 4.1

For the Class Demonstration

- (1) 250mL beaker
- (1) straw or glass tubing (glass tubing with a diameter of 5mm or 7mm); if using a straw, it should be clear enough to see the level of the water in it.
- (1) ruler or meterstick*
- food coloring (red or blue)

For Each Student

- Activity Sheet 4.1

*This item is not included in the kit.

Activity 4.1 – Constructing a Barometer

In this activity, you will construct a glass barometer so that students can observe the effect of air pressure. They will record their observations daily for two weeks. While this activity will span two lessons, it gives students the opportunity to collect their own data and observe air pressure changes.

Suggested Prompts

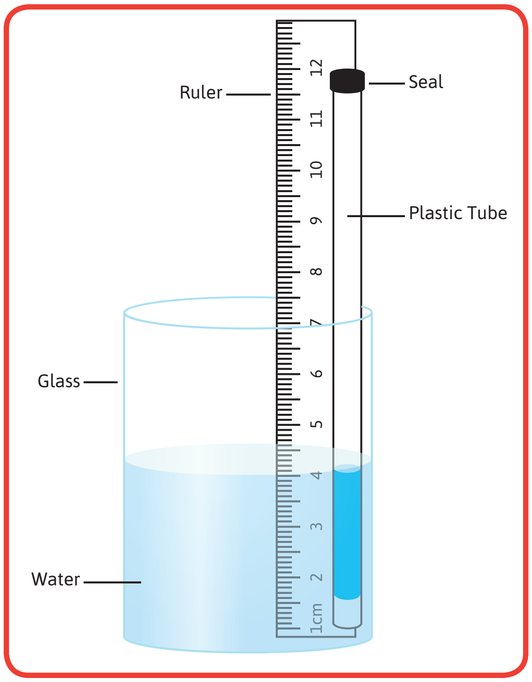
- What do you think *air pressure* means? (Use this question to construct a working definition of air pressure. This definition will be revised at the end of this activity and added to the word wall.)
- Do you know what instrument scientists use to measure air pressure? (*Students may have heard of a barometer or barometric pressure from listening to weather reports or previous science classes.*)
- Do you think there is air pressure in the classroom? Why?

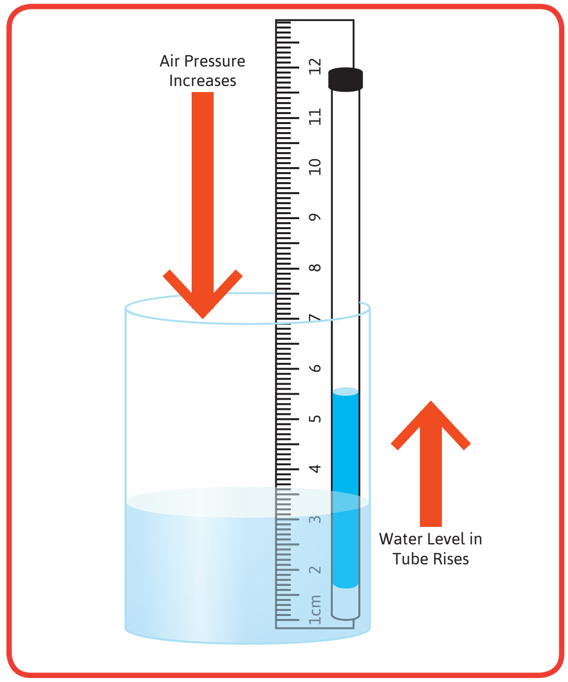
In this activity, construct a glass barometer for the class in order to see if they can measure air pressure. Explain each step of the setup and use the prompts to help students understand each of the parts.

Procedure for Setting Up the Barometer

1. Place a ruler in a large beaker with straight sides and tape it to one side. Make sure the numbers are visible. Review with students the markings on the ruler and how to read the measurements.
2. Tape a piece of clear plastic tubing onto the ruler in the beaker. Make sure the tubing is not touching the bottom of the beaker.
3. Fill the beaker about halfway with water. Add a drop or two of food coloring and mix. Ask students why they think you are adding the food coloring. (*The food coloring is added in order to see the change in water level more easily.*)
4. Using the tubing like a straw, carefully draw water up the tubing until the water level is the same in the beaker and the tubing. This means that the pressure is the same inside the tube and outside. Ask students why making sure that the pressure is the same inside and outside the tube is important. (*Beginning with equal pressure makes any changes easier to see.*)
5. Using your finger, trap the water in the tube. Then seal the end of the tube with modeling clay. Make sure that no air can enter the tubing. (You may need to add more clay after a day or two to make sure the seal is still tight.)
6. Record the level of the water in the tube. Ask students why it is important to record the starting level. (*In order to observe change, it is important to know the starting water level.*)
7. At the same time every day for the next 10 days, record the water level in the tube.

Example Setups





Making Predictions about the Barometer

Once the setup is complete, have students fill out the first section on Activity Sheet 4.1. If students are having difficulty with their predictions, use the following prompts:

- If you think that air has pressure, where in your setup would the air be able to push down? (*The air would push down on the water in the beaker.*)
- Why is it not pushing down on the water in the tube? (*The tube is sealed.)*
- Can the water from the beaker get into the tube? (*Yes, it can get in through the bottom of the tube because it is not sealed.*)
- If there is more pressure pushing down on the water in the beaker, where will it go? (*Students should be able to reason that the only place it can go is into the tube. Therefore, the water level in the tube would rise.*)

Give students a few minutes to complete their activity sheets. Explain that they will come back to the data they collect about air pressure at the end of Activity 4.3. The class barometer will allow students to observe that air exerts pressure on what is below it. Since readings need to be taken over several days, students will continue to investigate what is happening with weather conditions to create a storm. Using the class model, summarize with the class what they know about what is happening.

Suggested Prompts

- What do you know about the air mass on the left side of the model? (*It is denser, has higher pressure, and is cooler than the air mass on the other side of the model.*)
- What about the other side of the model? (*It is less dense, has higher pressure, and is warmer.*)

Label the high- and low-pressure areas on the model.

- Which way did the air move when convection is taking place? Cooler to warmer or warmer to cooler? (*Cooler, more dense air moves towards warmer, less dense air. We saw this in the convection box.*)
- Since you know that convection does not always cause a storm, what else could be going on here?

Students know that temperature/density differences cause convection. Ask: "Could the size of the difference in temperature/density between the two air masses make a difference?" In the next activity, students will try to figure out the answer to the question.

Materials – Activity 4.2

For the Class Demonstration
- (2) large beakers to mix food coloring and water
- (2) clear plastic cups (6–8oz)
- red and blue food coloring
- warm and cold water*
- (1) index card* (or piece of rigid plastic of similar size)
- duct tape* (optional)
- (1) pan
- paper towels*

*This item is not included in the kit.

Activity 4.2 – Temperature Difference and Movement of Air Masses

Demonstrating How Temperature Differences Cause Water to Move

Since students already know that convection occurs because of temperature differences, they need to figure out why convection does not always cause a storm. In this demonstration, they will observe what happens when there are two different temperatures of water that come in contact with each other. You will need to do this demonstration twice, first with blue and red water that have approximately the same temperature. (See Lesson 4 Setup.)

In Lesson 2, students learned that water and air are both fluids and they behave in similar ways. Because of this, scientists often use water to represent air because it is easy to see. Because water is clear, food coloring will be added to the water in this demonstration so that students can see where the cold and hot water are moving. This is similar to the use of smoke in the convection box.

At the end of the last activity, students described the movement of air in the convection box as going from cooler, denser air to warmer, less dense air. Ask students if they think that the water in this demonstration will move the same way.

Since students are trying to figure out if the amount of difference between air masses affects the way they move, let them know that you will do this demonstration twice. The first time, both cups of water will have similar temperatures, so there is little difference between them. The second time, one cup will have hot water and the other cold, so there will be a large difference in temperature.

Briefly show students the setup of the first demonstration. Have them predict what will happen to the red and blue water of similar temperatures when you remove the card. Then proceed with the demonstration. (See Preparation section for directions.)

Trial 1: If this is done correctly, when the cups are turned, the students should be able to see a purplish area between the two water masses. They should also see the blue, colder water move under the red, hot water and push it up.

Trial 2: This time, students should see only a small amount of mixing of the two colors. They should see that the blue, colder water moves under the red, hot water and pushes it up.

After finishing Trial 2, have students complete questions 1 and 2 for Trial 2 on their activity sheets.

Making Sense of the Demonstration

Use the following prompts to discuss what students observed in the demonstration:

- What was the difference between the cups in Trial 1 and Trial 2? (*In Trial 1, the two cups contained water that was the same temperature. In Trial 2, one cup had hot water and the other cold.*)
- Were the results the same in both trials? If not, how were they different? (*When the water masses were similar in temperature, they blended easily. When there was a large difference between the water masses, a boundary formed and the cold water moved under the hot water and pushed it up.*)
- Why do you think the cold water moved under the hot water in Trial 2? (*This should be linked to density differences just like in the convection model. Colder, denser water moved toward the warmer, less dense water. Because it is denser, it stayed on the bottom and lifted the warmer, less dense water up.*)
- How is what we just saw different from the convection box? (*There is no constant heat source in the cup. In the convection box, the cooler air moved in to fill the space left by the rising, warmer air. This continued as long as the air was being heated. In Trial 2, the hot, less dense water was rising not just because it was less dense. It was also being pushed up by the denser, cold water. The difference in temperature between the hot and cold water was much larger than the difference in Trial 1. The mixing could not take place as quickly, so the more dense water pushed the less dense water out of the way.*)
- Do you think that when two air masses collide similar things could happen?
- What would happen if the two air masses had similar temperatures? (*They would blend together quickly.*)
- What would happen if there was a large temperature difference between the two air masses? (*A boundary would form between them. Because the temperature difference is large, they could not blend together quickly. The cooler air mass would sink under the warmer one and push it up.*)

Students should be able to say that both water and air are fluids and behave the same way.

That is why water was used in this demonstration. Therefore, if two air masses collide, the results would be the same. Return to the model of air movement in the atmosphere from Lesson 3 and review what it shows. The following ideas are identified in the discussion questions that follow, and should be added to the model.

- High/low pressure—Based on density, students should label the denser air mass as high pressure, and the less dense air mass as low pressure.
- Front—This is the boundary between the less dense and denser air mass.
- Instability—Air is said to be unstable when the two masses do not mix quickly and the warmer air continues to rise within the cooler air around it.
- Lift—The cooler, denser air mass moves under the warmer, less dense air mass and pushes it up.

Suggested Prompts

In Activity 4.1, you learned that air that is denser exerts more pressure on what is below it, and you labeled the high- and low-pressure areas on your model.

- Why does the denser air mass exert more pressure? (*There are more molecules in the same amount of space, which means more mass and more pressure.*)
- Does the model from Lesson 3 show two air masses of different temperatures and densities coming together and forming a boundary? (*Identify this on the model and let students know that this is called a front.*)
- Does the model show the cooler air mass moving under the warmer one? If not, how could you show that? (*Draw an arrow to show the cooler air mass moving toward the warmer one. If students suggest another way to show this, use their ideas as long as the meaning is clear. Point out that this also shows the denser, higher-pressure area moving toward the less dense, lower-pressure area. It is important for students to understand that air masses move from high pressure to low pressure.*)
- What happens to the warmer air mass when the cooler one moves under it? (*The warmer air mass is pushed up. Let students know that this is called lift.*)
- How could you show the warmer air being pushed up by the cooler air? (*Draw an arrow pointing upward in the warmer air mass.*)
- What happens when there is not much difference in temperature between the two air masses? (*The two air masses blend easily.*)

Equilibrium

Let students know that this blended state is called *equilibrium*. If they are not familiar with the term, prompt them to think through a definition.

- Reaching equilibrium in the air can happen quickly or slowly.
- In the activity with the cups and water, in which trial did you see the two masses mix quickly?

Trial 1

- Was there much temperature difference between the two masses in that trial? (*no*)
- Did you see lift? (*no*)
- When equilibrium is reached quickly, what do scientists call the atmosphere? (*stable*)
- What is it called if equilibrium is not reached quickly and the warmer air continues to rise within the cooler air around it? (*instability*)

Trial 2

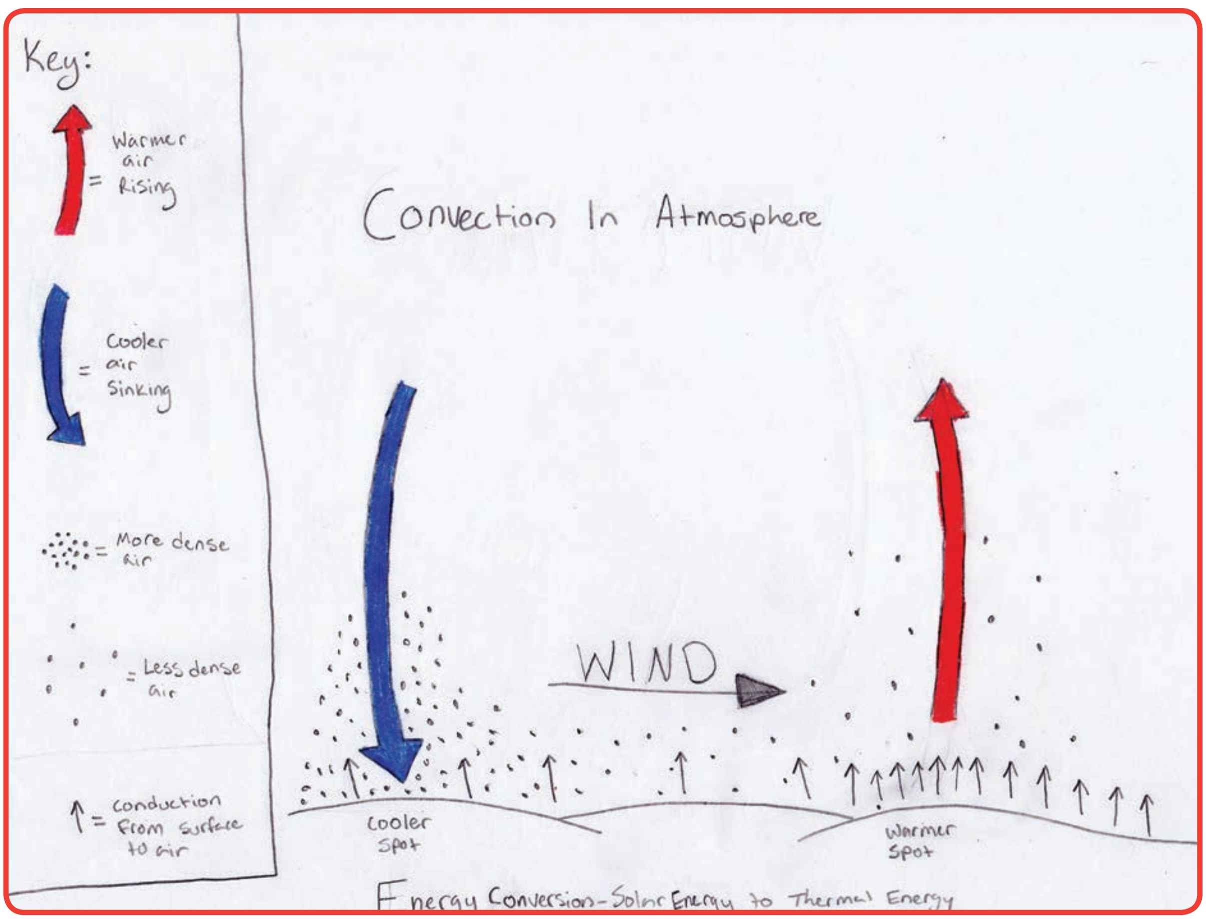
- Was there much temperature and density difference between the two masses of water in Trial 2? (*Yes, there was a much bigger difference between the two water masses than there was in Trial 1.*)

- Where on the model would the air show instability?
- How can you show instability on the model? (*Suggest to students that they write the word instability along the arrow showing lift. The lift is causing the air to become unstable, because of the temperature differences between the rising air and the air around it.*)

Once the model from Lesson 3 has been revised, post it on the DQB. The class model should include the following (see sample revised model):

- cooler and warmer air masses showing the arrangement of molecules in each one
- the density of each air mass , labeled: cooler air mass = *denser*; warmer air mass = *less dense*
- high- and low-pressure air masses
- warmer air mass rising and a label indicating energy transfer (convection)
- line showing the boundary between air masses, labeled *front*
- arrow showing cooler air mass pushing under warmer air mass
- arrow labeled *lift*, showing the direction of the lift
- area of instability, labeled along the lift line

Revised Model



Ask students the following questions:

- Do you have everything in this model to produce a storm?
- Are there still conditions that are not accounted for in the model? (*Clouds and precipitation are still missing.*)
- Where does the energy come from in a storm?
- Why are those necessary elements for a storm?

In the next activity, students will build on their prior knowledge about clouds and precipitation and add those ideas to the model from Activity 4.2.

Materials – Activity 4.3

For the Class
- PI: Cirrus Clouds
- PI: Cumulonimbus Clouds
- PI: Altocumulus Clouds
- PI: Fair Weather Cumulus Clouds
- PI: U.S. Surface Analysis Map
- storm video* (Refer to the Preparation section.)

For Each Student
- Activity Sheet 4.3

*This item is not included in the kit.

Activity 4.3 – Is a Storm Cloud Different from Other Clouds?

Discussion: Brainstorming

Articulate that all clouds are not the same and do not all produce rain.

Brainstorm with students what they know about clouds. The purpose here is to arrive at the idea that all clouds are not the same and that all clouds do not produce rain. Use PI: Cumulonimbus Clouds, PI: Altocumulus Clouds, PI: Fair Weather Cumulus Clouds, and PI: Cirrus Clouds to help students visualize various types of clouds they may have seen. Ask students the following questions:

- What is similar and different about these clouds?
- Which of these clouds do you think will produce rain? Why do you think that?
- What do you know about how clouds form?

Students may use terms like *condensation*, *water vapor*, and *humidity*, and also make reference to the *water (hydrologic) cycle* (IQWST ES1, IC1).

- What happens to the water at the Earth's surface? (*It evaporates and changes into water vapor. The water vapor condenses and becomes liquid and returns to the Earth as precipitation.*)
- Can you think of everyday examples of this cycle? (*Students may use various examples for evaporation, such as puddles drying up after a rainstorm, water evaporating from a glass, floors drying after being mopped, and wet towels drying. Students may use various examples for condensation, such as the bathroom steaming up when taking a shower causing water to condense on the mirror, and water condensing on the outside of a glass or can of soda.*)

If students worked with the IQWST ES1 unit, they studied the water (hydrologic) cycle. They used an aquarium to demonstrate the processes of evaporation, condensation, and precipitation. They put soil in the aquarium, added water, and covered it with plastic wrap. After sitting overnight, students were able to observe that water evaporated from the soil, condensed on the inside of the plastic wrap, and then dropped into a Petri dish sitting on the soil in the bottom of the tank (precipitation).

Suggested Prompts

- What do you call water vapor in the air? (*It is called humidity.*)
- What examples do you have that there is humidity (water vapor) in the air? (*Students may use examples such as feeling sticky in the summer. Condensation is also an example of water vapor in the air. The water that is condensing is coming from the air and not from the thing on which it is condensing. For example, the condensation on the bathroom mirror after you take a shower is coming from the water vapor in the air, not the mirror.*)

Record the following words on the word wall: *evaporation*, *condensation*, and *precipitation*. These three processes move water in the atmosphere.

Ask students if they know what happens when water condenses in the atmosphere. (*Students should know that this forms clouds, because water vapor in the atmosphere condenses around particles of dust and other material in the atmosphere and forms a cloud.*)

At the beginning of this activity, students looked at pictures of different cloud types and tried to figure out which one might produce rain or a storm. They have identified the three processes that move water in the atmosphere. In this activity, they are going to view a video of a building storm cloud and try to determine what is occurring.

Storm Cloud Video

Have students take out Activity Sheet 4.3. Explain that they are going to watch a video showing a building storm cloud. Let them know that they will see the video twice. The first time, they should simply watch and observe what is happening. Then, give them time to read through questions 1a–1d on their activity sheets. This will give them a focus for viewing the video the second time. Show the video again, and then have them answer the questions.

Using the questions on the activity sheet, have students share what they observed in the video. Students may answer some of these questions differently. Encourage them to share all their observations.

- What happens to the shape of the cloud? (*Observations may include the following: it gets bigger; it looks like clouds are forming inside of the bigger cloud; it is rising from the ground; and later, there are little clouds coming out of the top.*)
- What happens to the size and shape of the cloud? (*It gets wider and taller.*)
- Are all parts of the cloud behaving in the same way? Explain your answer. (*In some parts, there are smaller clouds forming. Some parts of the cloud are getting taller.*)
- What happens to the top of the cloud? (*Little clouds come out of the top. Following this, the top becomes flat and it does not get any taller.*)
- Was there anything else you noticed about the cloud?

At the end of Activity 4.2, students identified clouds and precipitation as two things that still need to be added to the model.

Discussion – Synthesizing

Purpose

Synthesize prior knowledge and complete the storm model.

The purpose of this discussion is to use the concepts from previous lessons and units to complete the storm model. Begin the discussion by referring to the Word Wall and evaporation, condensation, and precipitation.

Suggested Prompts

- What is evaporation?
- If water continually evaporates from the Earth's surface and changes into vapor (humidity), do you think evaporation and humidity should be added to the storm model? Why?
- What examples of evaporation do you know? (*puddles evaporating after a rain, water evaporating from a glass that sits overnight, towels drying*)

In the IQWST IC1 unit, students learned that evaporation occurs when molecules at the surface of a liquid gain enough energy to enter the gas state.

- In your model, where do you think evaporation is occurring? Why? (*Evaporation occurs near the surface of the Earth. That is where the reservoirs of water are found and where air is heated.*)

At this point, add evaporation and humidity to the model. Humidity should be labeled as water vapor. (See the example of a completed model at the end of this lesson. This is only a sample and your class model should reflect student ideas.)

- What happens to water vapor when the air cools? (*It condenses and forms clouds.*)

- Air cools as it rises, because it is transferring energy to the surrounding air. (This was added to the model in Activity 4.2.)
- Water vapor in the air condenses and changes to liquid.
- In order for water to condense, it must condense around something. In the atmosphere, it condenses around dust and other particles in the air. This forms a cloud.

At this point, draw a cloud at the top of the model and label the area condensation. Indicate on the model that this is water vapor changing to a liquid and transferring energy to the surrounding air. In the video students saw earlier, they saw clouds continue to form higher and higher up. Ask students the following questions:

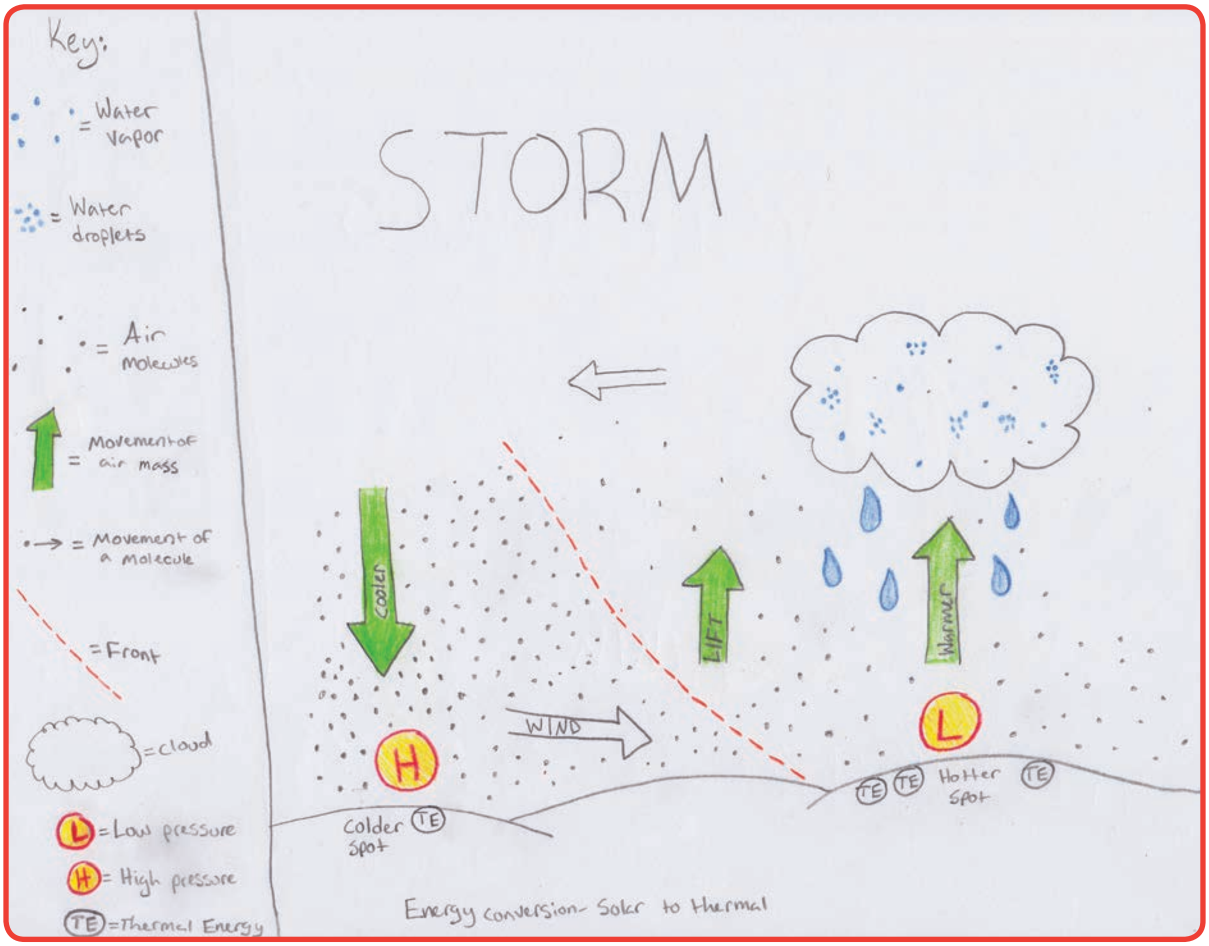
- What is happening to keep the clouds building up higher and higher? (*Students should be able to say that since condensation is transferring energy to the air around it, the air has more thermal energy and will continue to rise*.)
- What happens to that air as it cools? (*It will condense and form more clouds. This will continue until there is no more water vapor in the air and no energy to be transferred by condensation*.)

Wrapping Up the Lesson

- What do we know?
  - o Evaporation occurs near the surface of the Earth. That is where the reservoirs of water are found and where air is heated.
  - o Air cools as it rises because it is transferring energy to the surrounding air. (This was added to the model in Activity 4.2.)
  - o Water vapor in the air condenses and changes to liquid.
  - o In order for water to condense, it must condense around something. In the atmosphere, it condenses around dust and other particles in the air. This forms a cloud.
- What do we still need to learn?
- Does our model work?

In previous units, students have tested their model against actual data to see if it works and revise it if necessary. In the next lesson, students will test this storm model against data from an actual storm that occurred in Chicago, Illinois, in June 2010.

Sample Storm Model



Lesson 5

What Can Weather Maps Tell Us?

PREPARATION

Teacher Background Knowledge

Satellite Images

- The images of clouds on weather maps are taken by infrared satellites. Infrared satellite technology works by sensing the temperature of infrared radiation being emitted into space from the Earth and its atmosphere.
- Weather satellites not only sense this infrared light but also sense the temperature of the infrared emissions. The warmest emissions are displayed as dark grays on an infrared satellite image, while cold emissions are displayed as bright white. Computer enhancement of an infrared satellite picture increases the contrast between the different cloud features and the background, which makes more detailed analysis possible. Colors are added to make interpreting the image easier.

Radar Images

- Radar works by sending out a beam of energy, then measuring how much of that beam is reflected back and the time needed for the beam to return.
- Radar intensity is a way to see through rain. A pulse of energy is beamed through a cloud and the amount of echo returned will give the intensity of precipitation. The echo is actually a reflection of the energy, and a computer will generate a color code to indicate the amount of precipitation.
- Objects that reflect the beam back to the radar include rain, snow, sleet, and even insects. If more of the beam is sent back, the object is said to have a high reflectivity and is indicated by a bright color. Objects that return a small part of the beam have a low reflectivity and are indicated by darker colors.
- Television stations usually describe their radars as Doppler, but the images you see are almost always reflectivity images. Some radar operated by television stations have Doppler capability to show wind direction and speed, but the images are extremely complex and are much more difficult to understand than reflectivity images.

Measuring Pressure

- Scientists have several units of measure in which they report pressure. Most weathermen report pressure in inches of mercury (in Hg). This is what is seen on the weather report and in newspapers and is the unit of measure in the city data students received.
- Another unit of measure is the bar. The bar is a unit of pressure roughly equal to the atmospheric pressure on Earth at sea level. Pressure is also recorded in millibars: a millibar = 0.001 bar.
- Isobar is a line of equal or constant pressure. The prefix *iso* means equal, and *bar* is a unit of measure of pressure. Isobars are lines drawn on a map joining places of equal average atmospheric pressure reduced to sea

level. In meteorology, the barometric pressures shown are reduced to sea level, not the surface pressures at the map locations. This allows different locations to be compared regardless of elevation.

- Average sea level pressure is 29.92in Hg or 1013 millibars (mb).

Pressure Gradient

- The change in pressure measured across a given distance is called a *pressure gradient*. It is directed from areas of high pressure to low pressure. The pressure gradient force is responsible for triggering the initial movement of air.
- It is not necessary for students to learn the term *pressure gradient*, but they should understand the idea that the pressure changes gradually between the isobars. The closer the isobars are together, the stronger the wind.

Setup

In Activity 5.2, students will use the class barometer set up in Lesson 4.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Students who would be supported by additional practice with maps could use other local maps or maps from other areas or cities they have visited, cities where they have relatives, cities their families are from, cities they find interesting, or cities they are studying in social studies.

Lesson 5

What Can Weather Maps Tell Us?

TEACHING THE LESSON

Performance Expectations

Students will
- analyze weather maps to identify and track movement of high- and low-pressure areas.
- analyze weather maps to interpret data on cloud cover and precipitation.

Building Coherence

Students make the connection to the elements in their model from Lesson 4 and the symbols on weather maps. This is in preparation for interpreting data about a specific storm and using the model from Lesson 6. In addition, students will further develop their understanding of how air pressure is represented on maps and how it relates to fronts and weather.

Timeframe

3 Class Periods

Overview

Activity 5.1
Interpret the symbols on a weather map.

Activity 5.2
Investigate air pressure and its role in weather.

Introducing the Lesson

Students will test their models against actual data about a storm in order to see if it is correct. In this lesson, students will look at several different types of weather maps to learn how these conditions are represented. Review the model with students. Remind them that each piece of the model fits what they know, but they still need to see if all the pieces together can explain what they observe in a storm.

- Based on the model, what kinds of data would you need in order to test the model? (*temperature, humidity, wind, clouds, and rain [precipitation]*)
- What should you look for in the data? (*Did the temperature change? How? Did the humidity change or stay the same? Was there wind? Were there clouds? Did it rain?*)

Materials – Activity 5.1

For the Class
- PI: U.S. Surface Analysis Map (6/15/10)
- PI: U.S. Satellite Map (6/15/10)
- PI: U.S. Radar Map (6/15/10)

For Each Student
- Activity Sheet 5.1
- Reading 5.1

Activity 5.1 – What Can Weather Maps Tell Us?

Using Local Data
If you have access to a computer and projector, use local data for this activity. You would need a national weather map and also a regional one. The source used for the maps in this lesson was http://www.intellicast.com. You can access both national and regional maps at this site for all three types of data used in the discussion: clouds, precipitation, and pressure.

In order for students to fit the model to the storm data, they need to be able to interpret the information presented on weather maps, as well as numerical data. The maps in this activity are from June 15, 2010, and represent data collected within a one-hour period on the same day. This activity is to give students practice interpreting the information on weather maps.

This activity is structured around a series of weather maps. Before the class discusses each map, students will discuss each map in small groups and record their ideas about what the map shows as well as questions they have. Following each discussion, there is a list of the key ideas that students should have about each map.

Use PI: U.S. Surface Analysis Map (6/15/10)

This map shows clouds, precipitation, and pressure on a single map. This is the type of map that is used in weather reports on TV and in the newspaper. It can be difficult to interpret all of the conditions that are represented together on this map. In this activity, students will look at separate maps for each condition, in order to learn how each one is represented. They will return to this map at the end of the activity to see how all the data are combined into one surface analysis map to tell the weather story.

Have students use Activity Sheet 5.1 and work in small groups to answer Question 1a about this map. There is a copy of the map in the student book. When the groups finish, have them share their ideas and list them on the board. Use student ideas to identify the various representations on the map. Ask students the following questions:

- Have you seen this kind of map before? Where? (*Most students should be familiar with this representation from newspapers or TV weather.)*

Use the model from Lesson 4 on the DQB and connect that to what students saw on the map. This map is a combination of three different sets of data (cloud cover, precipitation, and pressure) that scientists have put together in one map. Prompt students to identify elements of the map and model that are similar.

- What elements of the model are represented on this map? (*Clouds, pressure, and possibly precipitation—this could be inferred because of the cloud cover.*)
- What do you think the letters H and L represent on the map? (*These represent areas of high and low pressure.)*
- What do the red and blue lines indicate? (*Red lines indicate warm fronts, and blue lines indicate cold fronts.*)

- What do you think the blue arrows and red circles on the lines show? (*These indicate the directions the fronts are moving.*)

On their activity sheet on line 1b, have students record any questions they have about this map.

Some classes may be more familiar with these representations than others. It is necessary that students understand what is shown in these representations in order to complete the activities in Lesson 6.

After the discussion, have students answer Question 1c about what they learned. If they still have questions, they should record those as well. Show students PI: U.S. Satellite Map (6/15/10). (There is an Annotated Map at the end of this lesson.) This map is a satellite map of clouds over the U.S. Begin by having students answer questions 2a and 2b about the cloud map on their activity sheet.

Suggested Prompts

- How is this map similar/different from the one you looked at first?
- What does this map show? (*Students' responses may include a map of the U.S., clouds, land, and water. This question is meant to facilitate student ideas about weather-related representations on maps.)*

Understanding the Image

- Depending on students' experience with maps, you may need to explain that in order to help understand where the clouds are located, lines have been added to the map to show where state and country boundaries are, along with lines of latitude and longitude.
- In the reading following the discussion, students will read more about satellite images of cloud cover, radar images of precipitation, and how they are produced.
- Some classes may be more familiar with these representations than others. It is necessary that students understand what is shown in these representations in order to complete the activities in Lesson 6.

This is a satellite image (taken from space) that shows clouds over the U.S.

- Are all the clouds the same color? (*Some are very light grey and others are very white.*)

Have students share what they know about visible light and infrared light (IQWST PS1).

- Visible light is light that they can see.
- Infrared light is light that they cannot detect with their eyes.

If students have worked in the IQWST PS1 unit, they have had experiences with visible light and developed a model to explain how they see.

The satellite that took this picture picks up the infrared light and shows the relative warmth of objects. Colder objects are brighter and warmer objects are darker.

- Which clouds in the picture are warmer? (*The clouds that are grey. These grey clouds are closer to Earth.*)

Students should relate this to what they have learned in Lesson 2 about air being heated from below. If these clouds are closer to the Earth's surface, they are being warmed by the surface.

- Which clouds in the picture are colder? (*The ones that look white. These clouds are higher and thicker.*)

Briefly discuss what students observe about the map. Make sure to include the following:

- Where are the most clouds located?
- What differences do you notice in the clouds? (*Most of the clouds are light grey or white, but some are light blue, dark blue, and even green and orange.*)

Let students know that the warmest (and lowest) clouds are shown in grey. As the clouds get higher, they are shown in white. The coldest (and highest) are shown in shades of yellow, red, and purple.

Explain that the choice of color is arbitrary and not standard. The shades of grey through white are standard and are what the infrared pictures show. The colors have been added to make interpreting the data easier. This is referred to as *false color*.

- Why do you think the clouds in the Gulf of Mexico appear to go from blue to green to yellow to orange? (*The clouds are getting higher as they go from blue to green to yellow to orange.*)

After discussing this map, students should be able to:

- identify clouds on a surface area map.
- explain what the colors on the map represent.

Allow students time to answer question 2c and record any questions they still have.

Replace the previous image with PI: U.S. Radar Map (6/15/10). On their activity sheet, have students record what they think this map shows and any questions they have about it. (Questions 3a and 3b)

Lead In

- The information on this map was collected at the same time as the previous map.
- Radar maps show where precipitation is currently located.
- This map indicates the type of precipitation and its intensity by color. Use the color key at the bottom of the map to explain the coloring scheme.

Type of Precipitation

- Rain is indicated in yellow to red to show light to heavy rain.
- Snow is indicated in light blue to dark blue to show light to heavy snow.
- A mix of rain and snow is shown in light pink to a dark coral.

Intensity of Precipitation

- Rain is shown in green, orange, and red. Green is light rain and red is heavy rain.
- Mix of rain and snow is shown in light pink to red. Light pink is light precipitation and red is heavy.
- Snow is shown in blue. Light blue means light snow and dark blue is heavy.

Have students identify the types of precipitation shown on the map and their intensity.

Most of what is shown is light rain (green). There are some areas of moderate (yellow) to heavy (red) rain. In the Pacific Northwest, there are some areas of mixed precipitation (pink).

Based on the storm model, ask students where they would expect to see clouds given the areas of precipitation they have identified. (*Students should indicate that there would be clouds where there is precipitation.*)

After discussing the satellite map and radar maps independently, project PI: Map Overlay, which shows the two maps merged on top of one another. (The states do not align perfectly, but the emphasis is on the weather data, which do align.)

After discussing PI: U.S. Radar Map (6/15/10) students should be able to do the following:

- Identify types of precipitation shown on the map.
- Label the intensity of the precipitation.
- Connect clouds and precipitation on the map.

Students should record anything they have learned about this map in Question 3c.

Students should know the following about air pressure (Lesson 4):

- High pressure means that the air mass is cooler and denser.
- Low pressure means the air mass is warmer and less dense.
- Cooler, more dense air moves to warmer less dense air. (Students saw this in the convection box in Lesson 3.)
- Air pressure can be measured. (Students measured air pressure with their class barometer, and there are air pressure measurements on their city data.)

Ask students what questions they have about this map. Generate a list of questions and record them on the board. Be sure the following ideas are included in the questions:

- What do the dotted lines mean on the map?
- Why are the spaces between the lines not equal?
- Does where the H and L are placed mean something?

In the next activity, students will work with a pressure map to figure out how scientists determine where the yellow lines on the map should go and what they indicate about pressure areas.

Introducing Reading 5.1 – How Do Scientists Get the Data?

This reading contains several images that students need to interpret based on the coloration. It will be available on the IQWST Portal for students to access. However, if that is not an option, it can be done in class so that the images can be projected. To access the IQWST Portal, you will need to log in to http://portal.iqwst.com and navigate to the lesson.

The homework is a reading about how satellite and radar images are obtained and what they show. Briefly discuss with them the kinds of images they have seen on weather broadcasts. Ask what they know about how these pictures are taken. This reading will help them understand more about how the images are taken.

Materials

For the Class:	*For Each Student*
• PI: Surface Area Map with Pressure Lines • PI: Pressure Map • PI: Map Overlay	• Activity Sheet 5.2

Activity 5.2 – Creating an Isobar Map

In this activity, students use a map of the U.S. that shows the air pressure readings for various locations. Have students turn to their city weather data and look at the reports of air pressure. Have several students report the data from one day in their city. Be sure to have them give the unit of measure. On the city data sheets, the readings are recorded in inches. Most weather reports are given in inches of mercury (in Hg). This is a measurement from a mercury barometer. Explain to students that another unit of measure for pressure is called a millibar. The values on the map students will use are in whole millibars. It is not necessary for students to understand how this measurement is derived.

Return to the questions on the board and remind students of what questions they still have about the surface area map. Let students know that in this activity, they will try to answer those questions.

Students will need Activity Sheet 5.2. Have students look at the map and let them know that the numbers on the map represent the pressure readings in millibars (mb) at specific locations in the U.S. Be sure to clarify that this activity is about how isobars and pressure areas are determined. It is different from their model because it does not show how storms are formed. In the last activity, students learned that the yellow lines on the surface area map indicated areas of equal pressure.

- On your map, do you see any readings that are the same?
- How could you create a line similar to the lines on the surface area map that showed areas of equal pressure? (*Students may suggest connecting the numbers that are the same.*)

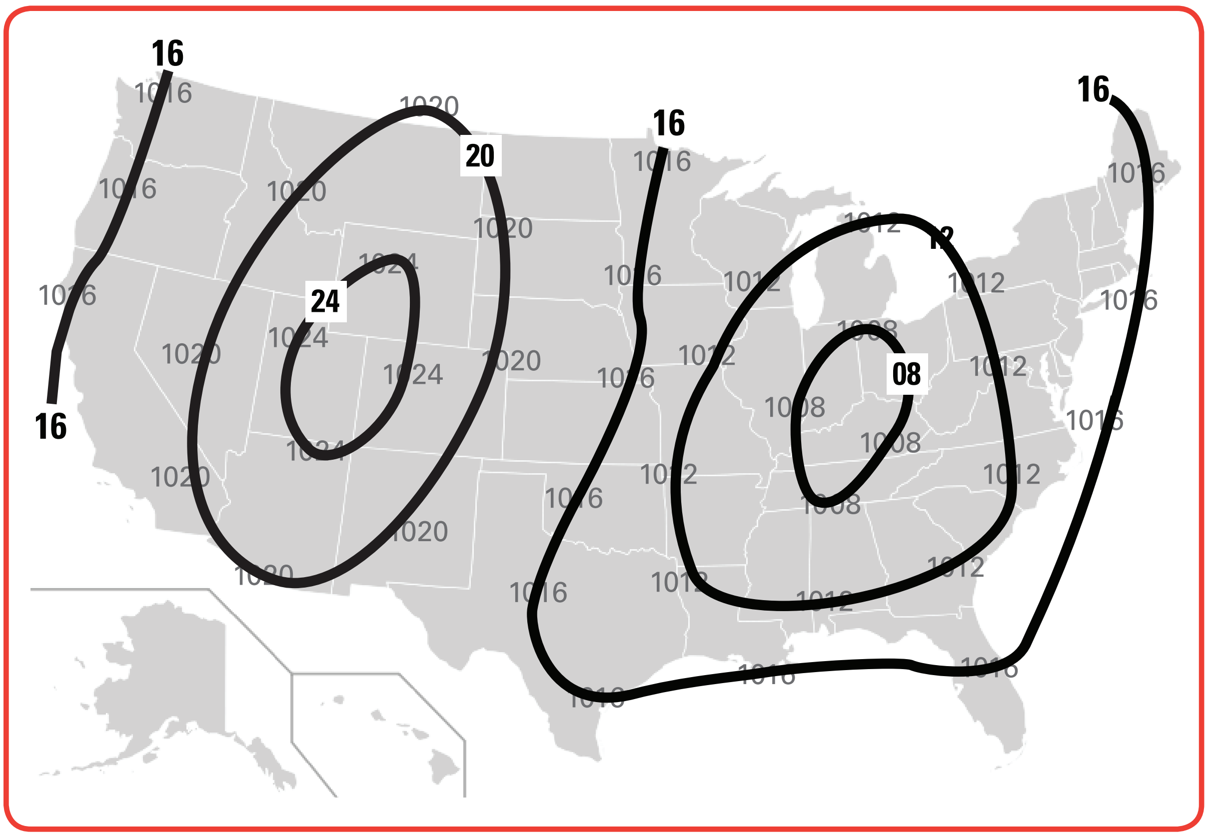
Use PI: Pressure Map and walk students through Step 3 on their activity sheet, filling in the images as they draw the lines on their maps. Be sure that students use pencils to do this activity, as they may need to erase lines in order to create isobars that do not cross.

- Use a pencil to lightly draw lines connecting identical values of air pressure. Begin by finding the 1024mb reading that is highlighted in blue. Draw a line to the next 1024 value to the northeast. Without lifting your pencil, draw a line to the next 1024 value located to the south. Then, connect that line to the one located to the southwest. Finally, return to the value highlighted in blue.

Students now have created an isobar, which is the line that connects areas of equal pressure. Have students look at the surface area map at the end of Activity 5.1, and ask if any of the yellow lines cross over each other. (*Students should see that the yellow lines all form irregularly shaped ovals and that none of the lines cross.*)

Remind them that as they continue this activity, they need to be sure that the lines they draw do not cross one another. Have students follow the directions on the activity sheet and continue to connect readings of equal pressure to create isobars. When they have drawn all the isobars, explain that each isobar needs to be labeled with the appropriate value. In order to make the map easier to read, scientists usually only use the last two digits of the pressure value to label the line. These labels are typically placed around the edges of the map at the end of the line. If the isobar is closed, a space is placed in the isobar with the value inserted into the gap. When completed, students' maps and the projected image should look like the following example.

Sample Isobar Map



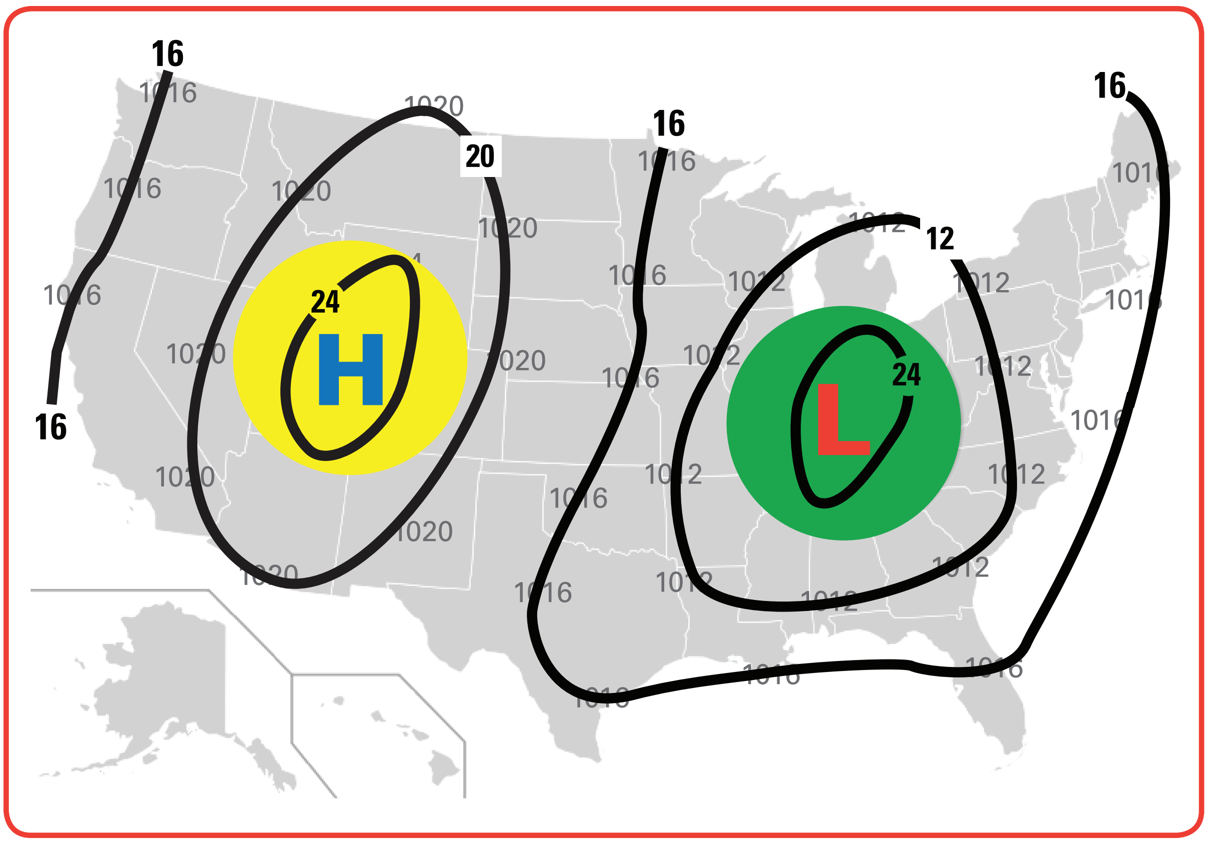
Have students complete Part 2 of the activity sheet by labeling the center of the high-pressure area with an H, and the center of the low with an L. Steps 3 and 4 ask students to connect the areas of high and low pressure to the type of weather they would expect to see there. Review what the class model shows about high and low pressure.

- Low-pressure areas are warmer and less dense.
- Low-pressure areas contain more water vapor.
- The air in a low-pressure area rises, cools, and the water vapor condenses.
- Rain (or some form of precipitation) usually occurs in the area of low pressure.
- High-pressure air mass is cooler and denser.
- The air in a high-pressure area contains less water vapor.
- High pressure usually indicates fair weather.

Students should shade in the areas using green where they would expect to see rain or snow. Then, using yellow, shade in where they would expect clear skies. They should also answer the Making Sense question on the last page of the activity sheet.

When students finish, the map should look like the following example.

Isobar Map Showing H/L Pressure Areas



(Yellow indicates area of fair weather, and green indicates rain or snow.)

When they finish, have students come up and show which areas they colored green and yellow. Have them explain why they colored those areas. Ask students the following questions:

- Do your maps look like this?
- Do you agree with the reasons for coloring the map this way?
- How is your map different?

Students should support their ideas with what they know about highs and lows from the class model. Use the discussion questions on Activity Sheet 5.2, so that at the end of this discussion, students understand that the change in pressure between isobars is gradual. (*Some students may think that the pressure remains the same until one isobar comes in contact with another, and then the pressure immediately changes. It is important that students understand that the change is gradual. The closer the isobars are to each other, the faster the change takes place and the stronger the wind.*)

Use PI: Pressure Map that now has the isobars, high and low centers, areas of precipitation, and clear weather on it. Ask students the following questions:

- What is the difference in pressure between the center of the high and the center of the low? (–16mb)
- Do you think that is a large or small change?
- Look at the distance between the isobars between the high and the low. Are they close together or far apart?
- Do you think that there will be a strong wind? Why? (*The isobars are far apart, so even though there is a big drop in pressure, the wind will not be very strong because the pressure is changing over a large distance.*)

Using the Map to Relate Pressure to Weather

Show PI: Surface Area with Pressure Lines and return to the questions from the beginning of this activity. Ask students if they now can answer the questions they had about the surface area map.

- What do the numbers on the yellow lines mean? (*The numbers on the line are air pressure readings. The yellow line connects areas of equal pressure. They are called isobars.*)
- Why are the spaces between the yellow lines not equal? (*Air pressure changes depending on the temperature and density of the air mass. Every place does not change at the same time or by the same amount.*)
- Does where the H and L are placed mean something? (*The H and the L on the map indicate where the center of the high or low is. It is the place of highest or lowest pressure in the air mass.)*
- Why do Ls appear where there are more clouds and Hs appear where it is clear? (*Low-pressure areas are warmer, denser, and contain more water vapor. As the air in a low-pressure area rises, it cools, and water vapor condenses. Rain [or some kind of precipitation] usually occurs in the area of low pressure. Areas of high pressure are cooler and denser. They contain less water vapor and form fewer clouds. They usually indicate fair weather.*)
- Where are clouds on the map? (*Clouds on the map are mainly where there are low-pressure areas. There is also some rain there, because there are areas of green indicating precipitation.*)

Some students may raise the question about the clouds in western Canada where there is a high-pressure area. If this comes up, you can explain to students that this is a mountain range and clouds often form, even in areas of high pressure, because of the evaporating snow increasing the water vapor in the air. Ask if students still have any questions about the representations on the map. At the end of this lesson, students should be able to use a surface area map to do the following:

- Identify clouds on a surface area map.
- Determine what the colors of clouds on the map represent.

- Be able to connect representations of clouds and precipitation on the map.
- Identify areas of precipitation (and the type).
- Identify areas of high and low pressure.
- Identify isobars and explain why the distance between them is important.
- Explain how pressure differences lead to wind.

Students began this activity with questions about the location of high- and low-pressure areas on the surface area map and about what the isobars (yellow lines) indicated. They should now understand how high- and low-pressure areas are determined and how they relate to weather.

Wrapping Up the Lesson

- What do we know?

  In this lesson, students have learned how to interpret the following representations of weather-related data on a surface area map:

  - cloud cover
  - precipitation and intensity
  - areas of high and low pressure and the direction of their movement
  - isobars

- What do we still need to learn?

  - Can we use a surface area map like the one in this activity in order to test our model?
  - Would we need other data? What kind?

In the next lesson, students will be given maps and additional data in order to identify patterns in the data. In the second activity, they will try to fit their model and the data together.

Lesson 6

Does the Storm Model Fit Data from a Storm?

PREPARATION

Teacher Background Knowledge

Troughs

- Weather is an extremely complex phenomenon. The model students created shows what happens at the surface along a single cold front. It does not consider that the single front they are explaining is part of a larger system. Upper-level troughs influence many surface weather features, including the formation and movement of surface low-pressure areas and the location of clouds and precipitation.
- Precipitation tends to fall to the east of the trough, while colder, drier air tends to dominate to the west of it. This happens because air rises to the east of troughs. As air rises, it cools, and its humidity begins condensing and forms clouds and precipitation. Air sinks on the west side of the trough and inhibits cloud formation and precipitation. The class model shows this same phenomenon happening at the surface.
- When there is an upper level trough as well as fronts meeting at the surface, the storm that is produced can be severe.

Dropping Pressure

- Conditions in the atmosphere change a lot over a small distance in the area of a thunderstorm. Where the rain is falling, the pressure tends to go up by a few millibars (about 0.1 inches of mercury). This is because, as the rain falls, some of it evaporates, which makes the air cooler and heavier.
- Another process is occurring that makes the picture complicated. As the air goes up into the thunderstorm's updraft, it creates an area of low pressure under the updraft that acts to pull air in from around the thunderstorm. This low-pressure region is also typically a few millibars lower than the environment of the storm. As the rain begins to taper off, the pressure begins to rise as the high-pressure region replaces the low.

Activity 6.2

Writing Explanations

- Students should write their explanation in a cohesive paragraph and not in three separate sections labeled claim, evidence, and reasoning. The question they are trying to answer is, why did the storm happen?
- Their paragraph should use the causal pattern in the data to explain why the storm happened. The data that they just analyzed are the evidence.

Sharing Explanations

- Some groups may have similar explanations but used different data to support them. Have these groups try to combine ideas and reach agreement about their explanations.

- Multiple groups with similar explanations do not all need to present them but rather share reasoning and evidence as one explanation is presented.

Setup

Specific instructions for activity setup are embedded within the lesson.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

1. Depending on students' ability to read and interpret graphs, the initial questions may need to be done in a more guided way. The activity is constructed so that students are working in groups to interpret the data. If the class struggles with this, it may be necessary to walk through the first graph with them.

2. Students may need support in understanding the precipitation chart. The number at each time stamp indicates the amount of rain that has fallen since the last measurement.]

LESSON 6

Does the Storm Model Fit Data from a Storm?

TEACHING THE LESSON

Performance Expectations

Students will
- apply their storm model to explain patterns in weather.
- evaluate the fit of the model against the data.

Overview

Activity 6.1

Analyze data about a storm in order to identify patterns in the data.

Activity 6.2

- Apply the consensus storm model to data about an actual storm.
- Adjust the consensus model, if necessary, and update the DQB.

Building Coherence

In this lesson, students will apply the model of a storm that they developed in Lesson 4 to actual storm data, revising their model as necessary. This lesson allows them to answer the first part of the Driving Question: What Causes a Storm? It leads to Learning Set 2 and the idea of global patterns rather than local patterns.

Timeframe

3 Class Periods

Introducing the Lesson

Refer to the storm model that is on the DQB and prompt students to think about how they have used models previously in science.

Ask students the following questions:

- What do you know about using models in science? (*Students who have done previous IQWST units will have developed a model of how they see in the IQWST PS1 unit. In the IQWST IC1 unit, they developed a model of the particulate nature of matter. If students have not done previous units, have them share examples of other models they have used.*)
- How did you decide if your model was accurate? (*In IQWST PS1, models explained the anchoring activity. In IQWST IC1 models were used to explain real phenomena or data.*)
- How do you think you could test the storm model that the class developed? (*Students should suggest that they would need data from an actual storm.*)

Materials – Activity 6.1

For the Class

- PI: Surface Analysis (6/2/10)
- PI: Zoomed Regional Map (6/2/10)
- PI: Chart of Conditions
- PI: Regional Map after Storm (6/3/10)

For Each Student

- Activity Sheet 6.1

Activity 6.1 – Can We Identify Patterns in Data?

Establishing the Need to Test Model against Actual Data

Refer to the DQB and the conditions that make up a storm.

- Which of these conditions would you want data about in order to test your model? (*Students may respond that all of them are important. The quantitative data that are included in this activity are temperature, air pressure, humidity, and precipitation.*)

Students will use the map to identify where clouds are located and precipitation is occurring. Clouds are not quantitatively measured.

- What does a surface area map show you about a storm? (*The surface area map shows what is happening at a specific place and time. It does not show how the storm develops or moves. Students should understand that a storm does not just instantly happen. It is a process during which conditions change.*)
- How do you know that it happens over time?
- Can you think of an experience with a storm that would support your idea?
- What does the class model show about the storm? (*The class model shows that many things occur to create a storm.*)
- Would you want data from just during the storm? Why?
- Would it be important to know what was happening before the storm? After the storm?
- How would that help you test the model? (*In order to see if the model works, students need to see the change taking place.*)
- Why would using data from a specific place at different times help us test the model? (*You could see how the conditions change at that place.*)
- If all the conditions in the model are necessary for a storm, how would understanding how they change help decide if the model works? (*Press students to see how this might help understand how the conditions in a storm are related.*)
- Does a change in one condition affect another condition?
- How does finding patterns in the data help us? (*We can check the patterns in the actual data against what is in the model.*)

Let students know that this lesson focuses on a storm that occurred in Chicago, Illinois, on June 2, 2010. The data they will use is actual data from the National Weather Service and was collected at Midway Airport in Chicago. The data show what was happening to the conditions at the airport during an 11-hour period from 8:51 PM on June 1, through 7:51 AM on June 2. All data about conditions (temperature, humidity, pressure, and precipitation) refer to what was happening at Midway Airport at the time indicated on the *x*-axis of the graphs or at the time points in the charts. It is important that students understand that their model shows what is happening to create a storm in a specific location. In order to test their model, they need to see how a storm develops in a particular location.

Analyzing the Data

Students will need Activity Sheet 6.1. All of the data and maps that students use in this activity can be found on the activity sheets. Begin by using PI: Surface Analysis (6/2/10). A copy of this map is also featured on the activity sheet. This representation is similar to the one used in Lesson 5.

Using what students learned in the previous lesson, have them interpret what they see on the map. The goal of this brief discussion is to focus attention on what they see happening in the Midwest. Include the following questions:

- Where are the clouds located? How do you know? (*Since city names are given on the maps, have students use those to indicate location of the clouds. They should indicate the heaviest clouds are over St. Louis, Chicago, Des Moines, and Kansas City. These clouds are white in color. Students should indicate that they know these are clouds, because they go from grey to white. They know some are high clouds because they are very white.*)
- Where is it raining? How do you know? (*The areas of green, yellow, and orange indicate areas of precipitation. It is raining over Chicago and Kansas City.*)
- Where are the high-pressure areas? Low-pressure areas? (*There is a high-pressure area over Atlanta. There are lows near Des Moines.)*
- Are there any symbols on the map that you did not see in the previous activity? (*Students should indicate the brown line to the west of the storms along the Illinois/Indiana border. There is a second one going from Kansas into Missouri*.)
- What is happening along these brown lines? (*There are storms.*)

Explain that these lines are called troughs. They are a second area of low pressure that is caused by upper level pressure. It creates another front where warmer, less dense air rises and creates precipitation. This makes the storm stronger and more intense.

- What does the model show about the connection between areas of pressure and rain? (*Students should understand the following:*
    - o *Rain forms where areas of different pressure meet.*
    - o *Rain forms just in front of where the two pressure areas meet, because that is where the less dense, lower pressure air is rising and forming clouds.)*

Remind students that they identified temperature, precipitation, humidity, air pressure, and clouds as important conditions to look at in a storm. They will try to identify patterns in each of those conditions. The patterns are divided into three groups:

- Before the storm (8:51 PM [6/1/10] to 1:51 AM [6/2/10])
- During the storm (1:51 AM [6/2/10] to 5:51 AM [6/2/10])
- After the storm (5:51 AM [6/2/10])

Each of the graphs has the same *x*-axis. Have students look at the graphs and ask the following:

- Why is it important that the graphs all have the same *x*-axis? (*Students should understand that in order to compare the data during the three time periods [before, during, and after], the data need to be organized around the same time points.*)

Students should draw vertical lines on each of the graphs to indicate the three time periods. They will come back to this and discuss how scientists figure this out using the data. Students will work in groups to use the information to complete the chart on the first page of the activity sheet. The chart has three columns indicating before, during, and after the storm.

Storm Periods

- Before the storm: 8:51 PM (6/1/10) to 1:51 AM (6/2/10). These data show the conditions at the airport before the storm.
- During the storm: 1:51 AM to 5:51 AM. As a cold front arrives in a particular place, the barometric pressure will fall and then rise. This is the point where the cold front reaches the airport. It is indicated by the extreme drop in temperature. The pressure continues to fall as the low-pressure air rises, creating clouds and releasing thermal energy. This causes the air to continue to rise and the pressure to drop.
- After the storm: 5:51 AM. Cooler, higher pressure air has replaced the warmer, lower pressure air that was present at the airport before the front moved through. The humidity also begins to drop after the storm.

- When talking about a storm moving through an area, they are talking about the air moving.
- This movement is both matter (air) and energy.

Have students work in groups and complete the chart and answer the questions on the activity sheet. Remind them that the goal of this activity is to identify patterns they see in the data. Completing this portion of the activity and the discussion that follow will take more than one class period. Students are asked to analyze four sets of data and complete the table. The Making Sense discussion that follows is critical to writing their explanation in 6.2. Be sure to spend adequate time on the discussion to ensure students' understanding of the data.

Discussion – Summarizing

Purpose

To summarize the weather data from the graphs.

Show PI: Chart of Conditions. Begin with the Temperature row and have one group share their ideas. Use the following prompts to develop consensus on what the chart should look like.

- Does everyone agree with the information about temperature in the first row?
- Where do you disagree? Why?
- What data do you have to support your idea?
- Does anyone have another idea and data to support it?
- Can we all agree about the pattern in the temperature data before, during, and after the storm? Once agreement has been reached, make sure the responses in the first row fit the consensus.

After filling in the first row, use the same prompts to work through each of the other rows. If students disagree with answers, make sure they support their challenges with data from the appropriate graph. At the end of this discussion, the completed chart should be similar to the following.

WEATHER CONDITIONS (AT MIDWAY AIRPORT) CHICAGO, IL	BEFORE THE STORM	DURING THE STORM	AFTER THE STORM
Temperature	Temperature remained steady.	Temperature dropped 8° at the beginning of the storm. During the storm, the temperature remained steady.	Temperature remained cool and stayed steady.
Air Pressure	Pressure was steady and then dropped right before the storm.	Pressure continued to drop during the storm.	Pressure rose sharply after the storm.
Humidity	Humidity remained steady before the storm.	There was a sharp rise during the storm.	After the storm, the humidity finally continued going down.
Precipitation	There was little to no precipitation.	The heaviest rain was between 2:51 and 4:51, with a total rainfall of 2.45".	Rain tapers off and then stops.

Have students complete the Making Sense question at the end of the activity sheet.

Homework

- Depending on how long the Making Sense Discussion takes, the question at the end of the activity sheet can be assigned as a homework question. The discussion of it is used as the wrap up to the activity.
- It could also be done in class and discussed immediately.

Using the Making Sense question from the activity sheet, have students share their ideas.

- Did you see what you expected in the data given your model?
- Which variable did you find surprising? Why?
- Did you see what you expected with other variables? Explain.

Be sure that students use specific evidence from the data to support their ideas. They should link the evidence from the data to the model. (*I expected to see the temperature drop after the storm because our model says that higher pressure, cooler air would move in. In the temperature data, the temperature dropped 8° at the beginning of the storm.*)

Students have interpreted a complex set of data and summarized the patterns they found in the chart. In the next activity, they will see if their model can explain the patterns.

Materials – Activity 6.2

For the Class
- PI: Temperature Data
- PI: Humidity Data
- PI: Pressure Data
- PI: Precipitation Data

For Each Student
- Activity Sheet 6.2

Activity 6.2 – Can the Storm Model Explain the Data?

Groups Analyze One Set of Data

Remind students that the goal of this lesson is to decide if the model of a storm that they developed can be used to explain data from an actual storm. This is how they will test their model and determine if it needs to be revised.

Return to the chart created in Activity 6.1 (PI: Chart of Conditions). Review the patterns students identified for each of the conditions. Using the model, link the conditions on the chart to the model.

- Are each of the conditions on the chart accounted for in the model?
- Are there items in the model that are not on the chart? (*wind, energy transfer, energy conversion, lift, instability, evaporation, and condensation*)
- How is the model different from the data you looked at? (*Students should understand that their model is descriptive and qualitative while the data is quantitative.*)
- How can you use the model to explain the data? (*Because there are patterns in the data, the model should describe those patterns.*)

Each group will use the model to explain the pattern in the data for that condition. They will record both what their model can explain and what questions they still have. After all groups have finished work on a single condition, groups will jigsaw in order to put together the whole storm story. They will use the data and their model to explain what happens to the matter and energy in the storm.

There are four data sets from the last activity (temperature, humidity, air pressure, and precipitation). Depending on how many students are in the class, more than one group may be working on the same data set. In order to ensure that all students can participate in the group's discussion, groups should not consist of more than three to four students. Even though students will only be working on one condition in the first part of this activity, they have all of the data sets on their activity sheet. During the jigsaw, they will record information about the other data sets.

Assign each group one of the conditions on which to work. They should use their model from Activity 4.3 and the data on this activity sheet for their assigned condition.

Discussion – Synthesizing

Purpose

Synthesize group data and revise model if necessary.

Once all groups have identified what the model can and cannot explain about the data and any questions they still have, the groups should jigsaw so that there is a representative from each of the conditions in the new group. The new jigsaw group should combine their information and see if another group can answer any of their questions. After combining their information, each group will write an explanation of the storm based on their model to explain what is happening to both the matter and energy during the storm.

When groups have finished writing their explanations, they will share them with the class. The goal of this discussion is to determine if the class model of a storm can be used to explain actual storm data and revise it if necessary. For this group sharing, have the projected images for this activity available for students to use if they want to reference specific data.

Have one group share their explanation with the class.

Suggested Prompts

- Do you all agree with this explanation of the storm based on the model?
- If you disagree, what data do not fit the model? Why?
- How did your group explain that piece of data?
- Is there other data that this group could have used to support their explanation?
- How was your explanation different?
- What data did you use to support your explanation?
- Does everyone agree?

Press students to question each other's reasoning and evidence about the model. Students should link matter and energy to the data and what the model shows is happening. Once all groups have presented, ask: "Is there anything in the data that the model cannot explain? What?" (*The model does not explain why the pressure continues to drop during the storm. It also does not show that the storm occurs over time, and that one condition changing affects other conditions.*)

Until now, students were not sure that their model worked to explain how a storm is created. Press them to think about their model.

- What are we claiming this model can do? (*It can explain how a storm occurs.)*
- Do you see anything missing from the model?
- Does the model need to be changed or adjusted in any way?
- Are you satisfied that this model explains how a storm occurs?

If necessary, adjust the class model and post it on the DQB.

Wrapping Up the Lesson

- Conditions (temperature, pressure, humidity, and wind) do not remain the same from day to day.
- As conditions change, the weather changes.
- Sometimes conditions interact to cause a storm.

Return to the Driving Question and ask students if they can answer either part of it. Students should be able to answer the part of the question that inquires, What Causes a Storm? Post their answer on the DQB. It should be similar to the following:

Conditions (temperature, pressure, humidity, and wind) do not remain the same from day to day. As these conditions change, the weather changes. Sometimes these conditions interact to cause a storm.

- What do we still need to learn?

Introducing Reading 6.2 – Is It Going to Snow or Rain or…?

In Learning Set 1, students have developed a model of a storm. Have them think about the kinds of storms that occur where they live.

- Does a storm always have to include rain?
- What other kinds of storms are there?
- What kinds of storms do we have where we live?

Lesson 7

Why Does Temperature Vary in Different Locations?

PREPARATION

Teacher Background Knowledge

Equator, Latitude, Longitude

The equator is the largest circle that can be drawn on the spherical Earth. It separates the Earth into Northern and Southern Hemispheres. Each line of latitude is actually a circle on the Earth parallel to the equator, and for this reason, lines of latitude are also known as *circles of latitude* or *parallels*. The equator is 0° latitude, and the North and South Poles are located at 90° north and 90° south latitude, respectively. In other words, values for latitude range from a minimum of 0° to a maximum of 90°.

By middle school, students should have an understanding of latitude and longitude and how they are used to determine location on the Earth.

Light Sensor

- A light sensor measures the light intensity with the unit of lux. It is not important for students to know the definition of a lux. The important thing for them to understand is that a higher number means more light is entering the sensor.
- The light sensor has three setting ranges and each has a maximum value: the candle = 0 – 2.6; the bulb = 0 – 260; and the sun = 0 – 26,000
- If students consistently get the same reading, they likely do not have the sensor set on an appropriate range for the light they are measuring. For example, if they are always getting a reading of 260 with the light bulb setting, they need to change the sensor's setting to the sun level.
- Also, the light sensors may need to be reset after making a large number of readings. If the sensor is not reset, it will no longer make accurate measurements. The sensor comes with written instructions on how to reset it.
- See IQWST Overview for more information about probes.

Light

If students did the IQWST PS1 unit, they should understand the following key ideas:

- Light rays travel in a straight line.
- Light can be absorbed, scattered, or reflected.
- Light energy from the sun is absorbed by the Earth's surface and is then transferred to the air. This increases the thermal energy (TE) of the air. (This was addressed in Lesson 2.)

Setup

Activity 7.3 – Lantern Preparation

Materials

For Each Lantern

- large Chinese paper lantern (at least 22" in diameter)
- (7–10) pushpins
- (7–10) wonderfoam cubes
- pieces of white paper* (1/2" square). These are to place between the pushpin and the outside of the lantern.

Depending on the number of students in the class, you will need to prepare four to six lanterns. There can be four to five students in a group. Students can rotate jobs while taking the readings at each pin: reader, recorder, and person to hold the sensor.

*This item is not included in the kit.

Lantern Preparation

1. Remove the bottom 1/3 of the lantern. This opening needs to be large enough for students to insert their hands along with the sensor to take the readings.
2. This large-sized lantern has approximately 36 wires equally spaced that can be thought of as equivalent to latitude lines. The spacing between the wires is approximately 5°. Near the top and bottom of the lantern, the spacing between the wires changes, so that every two wires are 5°.

3. Beginning at the top of the lantern, insert a pushpin into a piece of paper and push it into the lantern just above the wire. On the inside of the lantern, the pin should be inserted into the cube of wonderfoam. Skip the next wire and repeat this procedure. Continue inserting pins, moving down the lantern until you have inserted two pins past what would be the equator on the lantern. The pushpins should be in a line moving down the lantern. (See previous picture.)

Activity 7.3 Setup

- To facilitate this activity, it is helpful to have stations with the lantern suspended from the ring stand and the light source opposite it set up before students enter the classroom. Students can complete the setup on their own, but they may need to take the readings the next day.
- If there is more than one class doing this activity, leave the setup in place. Setting it up and taking it down between classes is too time consuming.

⚠ Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

1. The introduction to this activity is optional based on students' knowledge of latitude/longitude. There is a brief review of these concepts at the beginning of Activity Sheet 7.1. More time may need to be spent on reviewing (teaching) the concepts, if students are not familiar with them.

2. If students are comfortable with plotting latitude/longitude, have them quickly plot the location of the cities on the world map, and then move to the temperature discussion toward the end of *Activity 7.1*.

LESSON 7

Why Does Temperature Vary in Different Locations?

TEACHING THE LESSON

Performance Expectations

Students will

- analyze climate data to determine the effects of latitude on average temperature.
- consider, test, and rebut the hypothesis that the average amount of daylight can explain the effects of latitude on temperature.
- use a physical model to test the effect of the curvature of the Earth on the intensity of light hitting the Earth at different latitudes.
- investigate and analyze data about how the angle of light hitting an object affects its intensity.
- construct and defend a model that explains the effects of latitude on average temperature in terms of how the angle the sunlight hits the Earth affects the intensity of the light.

Building Coherence

This learning set focuses on the second half of the Driving Question: Why Is Weather Different from Place to Place? Students make the distinction between climate and weather and look at why climate is a better way to compare conditions from place to place. Latitude, sunlight, and Earth's shape are investigated in order to answer the Driving Question. Students build on what they learned in Lesson 1 about weather and weather conditions. They use light and energy concepts to try to determine what affects the temperature of different cities.

Timeframe

4 Class Periods

Overview

Activity 7.1

- Use latitude/longitude to plot the location of group cities.
- Compare the average yearly temperature of each of the cities.

Activity 7.2

Analyze data about hours of daylight and its effect on temperature.

Activity 7.3

Determine if the shape of the Earth affects temperature at different locations.

Activity 7.4

Investigate the effect of angle on light intensity.

Activity 7.5
Construct an explanation about why temperature varies at different latitudes.

Introducing the Lesson

Refer to the DQB as students will address, Why Is Weather Different from Place to Place?

Use the following prompts to query students' prior ideas about weather in various locations:

- What do you know about weather in different parts of the U.S.? *(It is hotter in the south than in the north. Some parts are hot and dry [desert Southwest], and other parts get a lot of snow [upper Midwest and Northeast]. Any answers that address variation based on location are acceptable.)*
- What do you know about weather in different parts of the globe? *(It is cold at the poles, hot at the equator, hot and dry in the deserts, and not all areas are the same.*
- What do you mean by north/south when talking about the whole Earth?

Students should have the following understanding:

- *North* and *South* globally mean the distance north or south of the equator.
- Areas north of the equator are in the Northern Hemisphere, and areas south of the equator are in the Southern Hemisphere.
- How can we compare where cities are located on Earth?

Since students already know that location can make a difference in what the weather is like at a particular place from personal experience and the city data in Lesson 1, the first activity will focus on locating the group cities on a world map to see if there is any relationship between location and temperature.

Materials – Activity 7.1

For the Class
- (1) wall map of Earth*
- PI: Data Table on Temperature

For Each Student
- Activity Sheet 7.1

*This item is not included in the kit.

Activity 7.1 – How Can We Compare Cities on Earth?

Reviewing Latitude and Longitude

The beginning of this activity is designed to be a short review of latitude/longitude, as well as an opportunity for students to plot the location of their group cities on a map. While there is a world map on the activity sheet where students can plot the information, it is suggested that you also use a wall map, so that you can easily refer to it throughout this learning set. It is important for students to be able to easily see the relative location of these cities and their proximity to the equator. Students will frequently refer to this map.

In Lesson 1, each group looked at weather data for a particular city.

- How many of you think you could easily locate your group's city on a map?
- Is there any information that would help you locate it more easily?
- Have you heard the terms *latitude/longitude*?
- To what do those terms refer?
- Can you show me what you mean on the map?

- Lines of latitude/longitude—Imaginary lines on a map or globe that help identify locations on Earth.
- Latitude—Horizontal lines that run east to west. They indicate distance north and south of the equator. The numbers used to describe latitude are the number of degrees (°) from the equator. Latitudes labeled °N are north of the equator, and those with °S are south of the equator.
- Equator—An imaginary line on the Earth's surface that is the same distance from the North Pole and South Pole. It divides the Earth into a Northern Hemisphere and a Southern Hemisphere.

- Longitude—Vertical lines that run north to south.
- Prime meridian—The line of longitude that divides the planet into Eastern and Western hemispheres. The numbers used to describe longitude are the number of degrees east or west of the prime meridian. Longitudes labeled °E are east of the prime meridian, and those labeled °W are west of it.

Students should conclude that if they had the latitude/longitude of their cities, they could easily locate them on a map. Let them know that they will be given the latitude/longitude of each group's city to plot. The class will then share ideas and plot the cities on a wall map in the classroom.

Plotting City Locations on a Map

If students are familiar with latitude/longitude, begin the activity here with the plotting of the cities on the class world map. After the cities have been plotted, move to the discussion about temperature.

If students are familiar with using latitude/longitude to plot the location of cities, they can move directly to plotting the group cities on the map on their activity sheet. When students have finished, have the class come together and share where they plotted each city. On the wall map, have an individual student show the location of Atlanta, Georgia. Use a Post-it or other marker to identify the location and name of the city. When finished, there should be a clear, visual representation of each city's location that students can refer to. They should also make sure that the map in the student book is correct.

Remind students of the city data from Lesson 1. It was for a specific time (five days in January 2011). Ask students the following questions:

- Did you find the same conditions (variables) in all the cities? (*yes*)
- What were they? (*temperature, clouds, precipitation, wind, and humidity*)
- Were the values of those variables the same in each city? (*no*)
- Was the weather the same in each place from day to day? (*Remind students that weather means what is happening with the conditions at a specific location and time. Students can tell that the weather varied from place to place over those five days by looking at the data.*)
- What are some specific ways the variables were different? (*Students may suggest differences in any of the conditions, but they should cite specific differences in their answers. For example, it was 86°F on January 17 in Buenos Aires, Argentina, but in Oslo, Norway, it was 16°F.*)

In Learning Set 1, students learned that temperature was an important condition in determining what the weather would be like.

- What does it mean for one city to be hotter that another city?
- Students should understand that there are two ways to think about the previous question.

  1. On a specific day—Chicago is hotter than Phoenix.
  2. In general—Phoenix is usually hotter than Chicago.

Ask students the following questions:

- Which of the two previous examples depicts weather? (*Number 1 is an example of weather because it is talking about a specific location and day.*)
- What do you think would be a fair way to compare what the weather in different locations is usually like?
- Should you compare the temperature month by month?
- What about over a year?
- Which would give a better idea about what the temperature in a place is like?

Distinguishing between Weather and Climate

When scientists want to compare what weather is usually like in a place, they look at data about conditions over a long period of time. They use the term *climate* to refer to weather conditions in a particular place averaged over a long period of time. Scientists usually look at data over 30 years or more to determine climate in a particular location. Ask students the following questions.

- Do you think the location of the cities affects the climate?
- What data could be reviewed to check your ideas? (*Students may suggest data about any of the conditions [temperature, wind, precipitation, and so on].*)

In Learning Set 1, students created a model of a storm and saw that temperature played an important part in the creation of the storm. Guide students to the idea that temperature data would be a good place to start investigating the relationship between location and climate.

Have students turn to the data table at the end of Activity Sheet 7.1. This table gives the average monthly temperature for each of the group cities. Have students calculate the average yearly temperature for each of the cities and answer the Making Sense questions at the end of the activity.

Using PI: Data on Daylight, have students share the average yearly temperature for each city. If groups do not agree on the average, have a student come to the board and calculate it. Students should change any incorrect averages on their activity sheet. They will refer to this information in the next activity.

- *Temperature* is an important condition in determining weather at a particular location.
- *Weather* is what the conditions are like at a specific location at a specific time.
- Looking at temperature averages over a longer period of time tells us what the weather is usually like at a specific place. Scientists call this *climate*.

Refer to the model from Lesson 2 and the Scientific Principles about how the Earth and air are heated, and ask students the following questions:

- How is the air at the surface heated? (*It is heated by conduction from below.*)
- How is the Earth heated? (*The Earth is heated by absorbing sunlight.*)
- If areas near the equator are warmer, what does that mean is happening with the energy? (*Warmer means that more thermal energy is being transferred.*)
- If Earth's entire surface is heated by the sun, why does the data show that areas near the equator are warmer than areas near the poles? Record students' responses on the board.

  (*Have students brainstorm ideas about this question and record them on the board. Ideas may include the following:*

  - *Areas near the equator get more sunlight and that is why it is hotter.*
  - *Areas near the equator are closer to the sun.*
  - *Some places have six months of daylight and six months of darkness, so they do not get as much light as places at the equator.*)

- How could you test the idea that there are more hours of daylight at the equator? (*You can test it by looking at the yearly average of hours of daylight.*)
- Why is it important to look at the yearly average and not just a month or two? (*The hours of daylight may vary from month to month. If you only looked at a month where there were only a few hours of daylight, you would think that the place only got that much light all the time.*)

In the next activity, students will analyze data about the hours of daylight at each of the locations and compare that to their temperature data in order to try to determine if there is a relationship between the two.

Materials – Activity 7.2

For the Class	For Each Student
• PI: Data Table on Daylight Hours	• Activity Sheet 7.1 and 7.2

Activity 7.2 – Do the Number of Daylight Hours Vary in Different Locations on Earth?

Analyzing Data about Hours of Daylight and its Effect on Temperature

In this activity, students will use monthly averages of daylight hours to calculate the average yearly hours of daylight for their city.

Using Activity Sheet 7.2, students should complete the Prediction section. Have each city group calculate the average yearly hours of daylight for their city. Then, have groups jigsaw so that there is one person from each of the cities in the new groups. Each group should accomplish the following tasks:

- Share the yearly average of daylight hours from their city.
- As a group, answer Questions 1 and 2 from the Making Sense section.
- If any pattern was observed, what did it help explain about the relationship of temperature and daylight, or what questions did it raise?
- What conclusion did the group reach about the relationship between temperature and daylight based on the data?

Discussion – Making Sense

Purpose

Determine if the question about the relationship between hours of daylight and temperature has been answered.

Return to the data table at the end of Activity 7.2.

Did you notice any patterns in the average hours of daylight for the year? Did you notice any patterns in the daylight hours each month? Look back at the average temperatures from Activity 7.1. Do you see any connection between the hours of daylight and the temperature for each city?

- When you looked at the average number of hours of daylight per month, before you figured out the average, did it look like each city received the same amount of light? Give an example to support your answer. (*When you looked at each month and compared the cities, it seemed like they all got very different amounts of light. In January, Atlanta had 10 hours of daylight, Buenos Aires had 14, and Ushuaia had 16.3.*)

- Did you see any connection between the number of daylight hours in a particular month and the temperature? (*For example, Oslo gets 16 hours of daylight in May, and the average temperature = 54°F. Oslo gets 5.7 hours of daylight in December, and the average temperature = 27°F. Oslo is warmest when it gets the most hours of daylight and coldest when it gets the least.*)
- Did you notice this same kind of pattern for any other cities? Which ones?

At the end of this activity, students should understand the following key ideas:

- Temperature on a monthly basis varies from place to place and corresponds to the hours of daylight for the month (i.e., more daylight in a month, the higher the temperature).
- Average yearly temperature varies by latitude. It is warmer at the equator all year long and cooler at the poles.
- All places receive the same number of hours of daylight in a year, but it varies by month.
- Why does temperature vary in different locations on Earth?
- Does the data you have explain the temperature differences among locations?
- What could be going on here? (*If all places receive the same number of hours of daylight over the course of a year, then they should be getting the same amount of light energy heating them, so that cannot explain the temperature difference by latitude.*)
- Why do you think it is cooler at the poles and warmer at the equator?
- What other information might help you figure out why the temperature is different?

In the next activity, students will investigate what a possible cause is for these temperature differences at different latitudes.

Materials – Activity 7.3

For the Class
- (1) globe*
- (1) lamp with 150-watt bulb
- (1) light sensor*

For Each Group
- (1) prepared lantern model
- (1) ring stand

For Each Student
- Activity Sheet 7.3

*This item is not included in the kit.

Activity 7.3 – Does the Earth's Shape Affect Temperature?

Introducing the Model

Students left the last activity with a question about why latitude seems to have an effect on temperature. They have seen data that showed the following:

- Temperature of a place varies over a year based on latitude.
- Places nearer the equator have a higher yearly temperature average than places that are farther from the equator.
- Monthly variations in temperature correspond to the number of hours of daylight the place receives. The more daylight in a month, the higher the temperature.
- Over the course of a year, all places on Earth receive the same number of hours of sunlight.

Lead In

- What do you know about light that might help you figure out what is happening with the temperature?

If students did the IQWST PS1 unit, they should understand the following key ideas:

- Light rays travel in a straight line.
- Light can be absorbed, scattered, or reflected.
- Light energy from the sun is absorbed by the Earth's surface and is then transferred to the air. This increases the thermal energy (TE) of the air. (This was addressed in Lesson 2.)

What would you need to know about the light in order to figure out why the temperature is different in different locations? (*Students may suggest that they could measure the light at different locations. Press them for suggestions about how to do this.)*

If students have done the IQWST PS1 unit, they will have measured light intensity using a sensor. If students have not had experience with light sensors, tell students that this is an instrument that measures the intensity of light at a specific location. Show students the round paper lantern and ask if they could use this as a model of the Earth. Explain that in this activity, they will use this model and a light sensor to measure the intensity of the light at different locations on the globe.

Students should understand the following about the model:

- The circle at the widest part of the lantern represents the Earth's equator. This represents 0° latitude.
- The wire remaining circles on the lantern are used to represent different latitudes.
- Each of the pushpins represents a specific location on the globe.
- Make the connection to the group cities on the map. Find the corresponding locations on the model for the cities north of the equator.
- All of the pins are above the equator and represent latitudes that are labeled °N on the data table.
- Ask students how the latitude would be labeled if the pins were lined up below the equator.

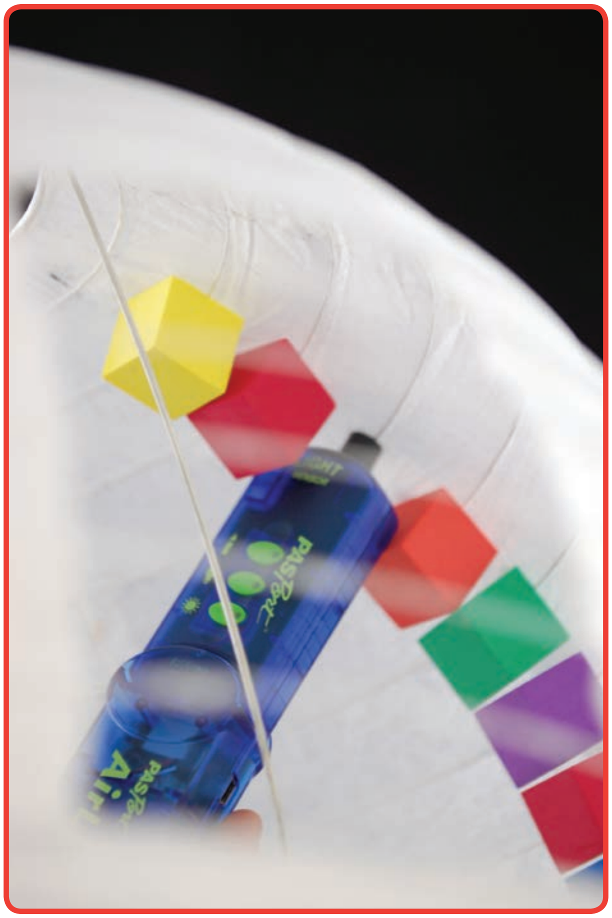
The following pictures show the lantern with the pushpins on the outside and the wonder-foam on the inside. The wonderfoam keeps the pushpins from tearing the lantern.

Demonstrate for students how to take the light readings using the model. You will need one student to help you do this.

- Have the students position themselves so that they can see through the hole at the top of the lantern.
- You should insert the probe through the opening in the bottom so that the side of the probe that shows the measurement is facing up. This is so that students are able to see the measurement through the hole in the top of the lantern.
- Place the tip of the probe on top of the wonder foam, so that it is perpendicular to the surface of the lantern. The wonderfoam will serve as a guide for students to keep the probe perpendicular.

Students may need support in understanding that they are taking the measurement of the light as it hits the surface of the Earth. The sensor should not be pointed at the light source, but pointed as if it were a person standing on the Earth.

The students should be able to see the reading on the probe and record it.



Explain to students that they should repeat this process for every pin on the lantern. It may take a little practice for students to be comfortable taking the readings.

Measuring Light Intensity Using the Lantern Model

Divide the class into groups of four or five students. Three students are needed to take each reading—one to manipulate the sensor, one to take the reading, and one to record the data. Students should rotate jobs within their group, so that each of them has the opportunity to use the sensor. Review with students how to use the light sensors.

Begin by having students answer the Prediction question on Activity Sheet 7.3. Assign each group a station with a model setup. (If you are having students set up their own stations, explain the procedure for getting materials and setting up the lantern.) Check each group to be sure they know how to take the reading based on your demonstration.

Note: It is particularly important that students hold the probe so that it is perpendicular to the surface of the lantern. They want to measure the intensity of the light as it hits the surface of the lantern. Remind them to use the wonderfoam as a guide for aligning the probe. After checking each group, have them take readings and complete the data table on their activity sheets. They should then complete the Making Sense section.

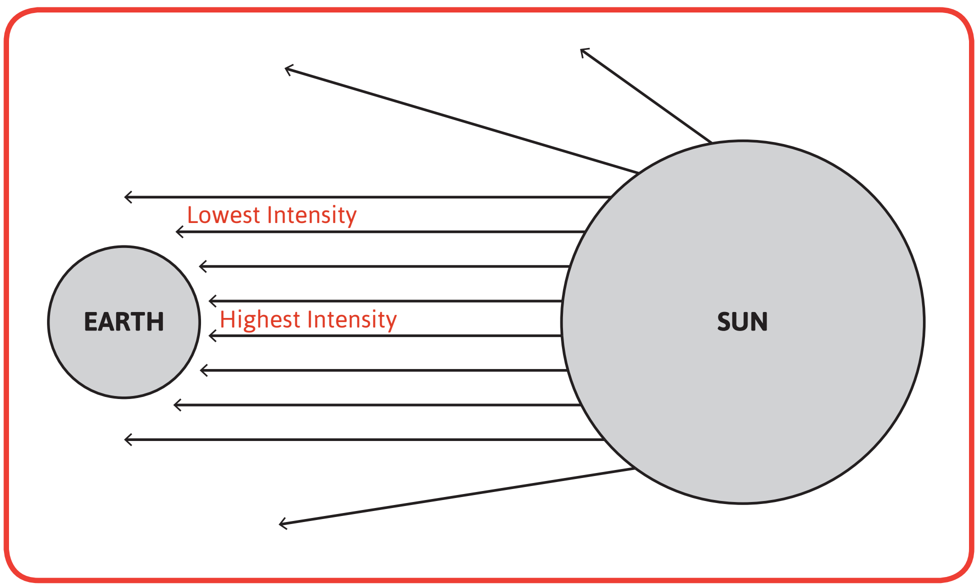
Comparing Group Data

Begin by sharing data that students collected. Ask them the following questions:

- Did you get the same intensity readings at each latitude?
- Where was the intensity reading highest? Lowest?
- What do you think causes this intensity difference?
- What do you think is different about the light at the equator and the higher latitudes?

Draw the Earth and sun on the board. Have a student come to the board and share a drawing from the activity sheet. Begin by having the student draw the light rays from the sun hitting Earth. The drawing should be similar to the following illustration.

- Label the place where their data showed the highest intensity, then the lowest.
- Draw a stick figure at the equator, one where the top ray hits the Earth near the North Pole, and another at a spot in between (for a total of three). Make sure student drawings show the figure standing on Earth. The stick figure at the equator should have its head pointed directly at the sun and its feet on Earth.



Using Stick Figures
It is important that students place stick figures on their Earth model, so they can visualize where the surface is. Using an X is not helpful in understanding the angle at which the sun hits objects on the Earth. This idea is critical in the next activity.

Have students compare the drawing on the board to their drawings on Activity Sheet 7.3. Ask if everyone agrees, or if there are changes that should be made to the class model. When everyone agrees with the model, allow students time to add the stick figures to their model and make any changes.

Ask students the following questions:

- Are all of the figures on the model hit by the light rays in the same way?
- Which one is hit most directly? (*the figure at the equator*)
- How is the light hitting the person standing closer to the North Pole? (*It hits the figureless directly, at more of an angle, from the side.*)
- Where did you get the highest light intensity reading? Lowest?

Have students add this information to the drawing.

- Did the light source change?
- Does the light hit the Earth the same way everywhere? (*Have students look at the stick figures and describe how the light is hitting each of them. For the figure at the equator, the sun is directly overhead. For the figure at the midlatitudes, the light is at a slight angle and not as direct. The third figure closer to the poles has light hitting it at a greater angle that is less intense.*)
- How do the intensity readings compare to your temperature data? (*The higher intensity readings correspond to the highest temperatures—at the equator. The lower intensity readings correspond to the lowest temperatures—closer to the poles.*)
- Do you think the direction that the light is hitting the Earth could make a difference in temperature? Why? (*Students may recognize that it is warmer in the summer [in the Northern Hemisphere] when the sun is directly overhead. If the sun heats the Earth, then maybe the direction the light hits the Earth could affect temperature. Press students to try to explain why. It is important to arrive at the idea of angle here.*)

It is not necessary for students to be able to explain this at this point, but they should begin thinking about this idea as they move into the next activity.

Students should leave this activity with the question, could the angle that light hits the Earth have an effect on temperature? In the next activity, students will investigate how the angle of light affects intensity.

Materials – Activity 7.4

For Each Group

- (1) piece of cardboard* (at least 8.5 × 11")
- (1) sheet graph paper*
- (3) different colored fine point markers*
- (1) flashlight

For Each Student

- Activity Sheet 7.4

*This item is not included in the kit.

Activity 7.4 – Does the Angle that Light Hits the Earth Affect Intensity?

Measuring Angle and Intensity

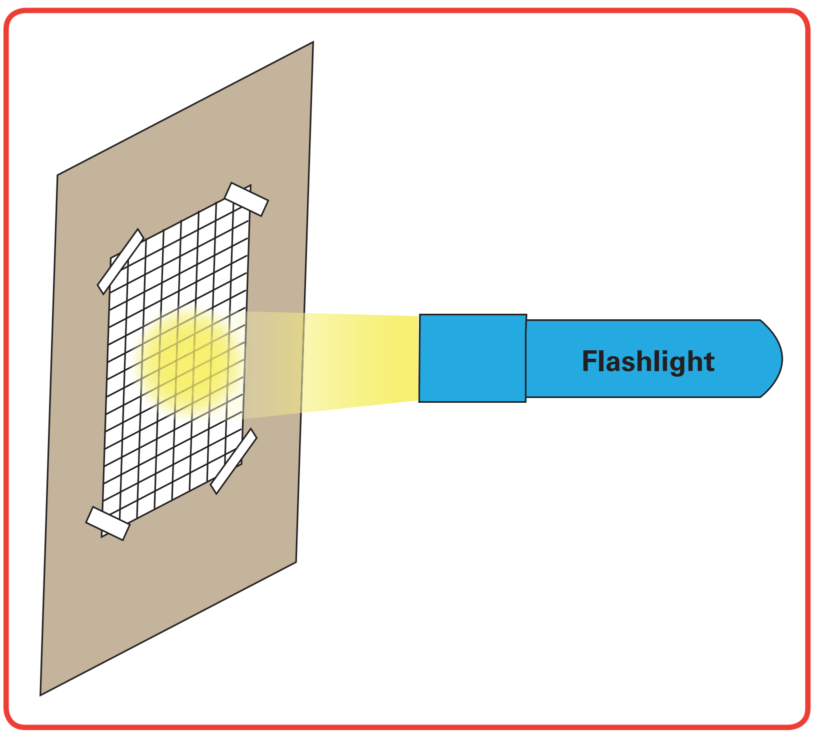
Students left the last activity with a question about the relationship of intensity to the angle at which light hits the Earth. Using the model from Activity 7.3, briefly go over what they have discovered so far.

- Light hits the Earth most directly at the equator and less directly farther away from the equator.
- Intensity goes down the farther away from the equator you get.

Ask students what is different about the way the sunlight hits those places. From the model, it looks like the angle is different. Point this out on the model. In this activity, students will measure what happens to light from the same source at different angles.

Working in groups, students should set up the activity following the directions on their activity sheets. You should check each group to be sure that their flashlight is two feet from the graph paper and shining on the center of the paper. Students should use books to support their flashlight. One person in the group should keep his or her hand on the flashlight, so that it does not move during the investigation.

Review the data table with students. Explain that measurement #1 represents light at the equator, #2 represents half way to the North Pole, and #3 represents an area almost at the North Pole.



Carrying Out the Activity

Each group will need to have at least three people: one to hold the cardboard, one for the flashlight, and one to draw the outline. Students should use a fine-point marker to trace the outline of the light on the graph paper. Markers are easier to use than colored pencils.

After students have drawn the outlines of the three beams on the graph paper, they should count the number of squares covered by each beam. Remind students that when they are counting the outer two outlines, they need to include all the squares that are inside the line. When they are counting the second outline, they need to include all the squares from the first outline as well. Let them know that it is the total area covered by the light that they should count.

Sharing the Data

Once all the groups have collected their data, have students share their results. Groups may not have the same exact count of squares for each angle of light, but they all should be within a similar range. If there are groups that are far out of range from the other groups, ask them to share how they collected their data and counted their squares.

Suggested Prompts

- Did the number of squares covered by the light change? Describe the pattern that you saw. (*There are more squares covered when the angle of the board is greater [near the North Pole] than when the board is straight [at the equator].*)
- Did the light source change in any way during the activity?
- Why would you get different numbers from the same light?
- What is different about the space covered at each angle?
- What did you notice about the light in the smaller outline compared to the larger one? (*Students should arrive at the idea that it is the same amount of light spread over a greater area.*)

Students should understand the following key ideas about light:

- Light is a form of energy.
- The amount of light reaching a location can be measured (intensity).
- If the same amount of light is spread over a larger area, there is less light energy reaching each spot, and it is less intense.

- How does the number of squares explain the temperature data from Activity 7.1? (*Students should connect the higher temperature at the equator with the greater number of squares. It also connects to the light intensity readings from the last activity. The light was more intense at the equator.)*

- If the amount of light energy did not change in each location, what caused the change in intensity? (*The only thing that changed in this activity was the angle at which the light struck the paper. This corresponds to the angle at which the light hits Earth. Students should conclude that the angle makes a difference.*)
- Where would there be less light energy? With a larger angle or a smaller one? (*There is less energy when the angle is larger. This corresponds to the temperature data and the angle data in this activity. Students should be able to support their answer with evidence from both activities.*)

Activity 7.5 – Can We Explain the Pattern in the Data?

In this activity, students are asked to write out a chain of reasoning and create a model that explains the pattern that connects temperature, latitude, and intensity of light.

Review with students each of the activities in this lesson and the ideas that they have added to the DQB. In this activity, they are to connect the ideas of temperature (7.1), latitude (7.2), light intensity (7.3), and the angle that the light hits the Earth (7.4) to construct an explanation for why temperature varies at different latitudes. This explanation should be a chain of reasoning that shows how each of these is connected and explain the pattern. They should also have a model that supports their explanation.

Sharing Explanations

Begin by having one group share their explanation and diagram about why the temperature is different at different latitudes. Record students' ideas.

Suggested Prompts

- Are there other groups that agree with the claim?
- Did you use the same evidence to support the claim? If not, what evidence did you use?
- What was your reasoning? How did you connect your claim and evidence?
- Do any groups have a different claim?
- What was your evidence to support your claim?
- How does it connect to your claim?
- Is there anything you would add to the diagram?

When all ideas have been heard, have the class combine their ideas into a single explanation for why the temperature is different at different latitudes. Record this on the board and have students record it in their books. At the end of the next lesson, students will return to this explanation and decide if they want to change it or add to it.

Wrapping Up the Lesson

- The temperature on Earth varies by latitude.
- The light intensity varies by latitude and corresponds to temperature.
- The angle at which light hits the earth affects intensity (more spread out, less intense) and therefore temperature.
- The sun hits the Earth most directly at the equator; therefore the light is more intense. This is where the highest temperatures were.
- What do we still need to learn?
- Does our explanation fit a new set of data?

Be sure these ideas are captured on the DQB.

Introducing Homework 7.5 – Do the Data Match the Explanation?

Use PI: January Average Surface Temperature. Explain that it is a visualization of the Average Surface Temperature for January (1959–1997). Remind students that a visualization is a picture representation of the data. Point out the key at the bottom of the page: red represents the hottest areas and blue the coldest.

This image is available on the IQWST Portal at http://portal.iqwst.com. Note: You will need to log in and navigate to the lesson so students can see the visualization in color. If students cannot access the IQWST Portal from home, time should be taken in class to project the visualization and discuss the representation. Students should label and write on their image so that they have the information they need to do the homework.

The homework requires students to use the explanation they created in class about the difference in temperature at different latitudes to explain what they see in a visualization of the January Average Surface Temperature (1959–1997). They are then prompted to write down any questions they still have. This will be used as the introduction to Lesson 8.

Lesson 8

What Else Is Affecting Temperature?

PREPARATION

Teacher Background Knowledge

Direction of Spinning on Axis and Revolving around the Sun

When students spin their Earth model, they should spin it in a counterclockwise direction. Later they will revolve it around the sun, also in a counterclockwise direction. This accurately represents the fact that Earth spins on its axis in the same direction that it revolves around the sun.

Shape of Earth's Orbit

The average distance of Earth from the sun is about 93 million miles. At its closest point, Earth is about 91.34 million miles from the sun; conversely the sun is about 94.45 million miles away when it is at its farthest point. Earth's distance from the sun remains relatively constant throughout its annual orbit. The shape of Earth's orbit is not quite a perfect circle. It is more like a stretched-out circle. Mathematicians and astronomers call this shape an ellipse. It can be long and skinny, or it can be very round. Scientists need a way to describe how round or stretched out an ellipse is. They use a number to describe this and call it the *eccentricity* of the ellipse. Eccentricity is always between zero and one for an ellipse. If it is close to zero, the ellipse is nearly a circle. If it is close to one, the ellipse is long and skinny. Earth's orbit is almost a circle. It has an eccentricity of less than 0.02. That is why the distance from the sun does not change much over the course of the year.

Earth's Tilt

Earth's north spin axis points almost directly at the North Star (within a degree). It always remains pointed this way at an angle of 23.5°. This is why the North Star always stays in the same spot in the sky and why other stars appear to move around it.

Teaching Strategy

Activity 8.2 – Implementing the Activity

- This activity is designed as a teacher-led, whole-class activity with students having their own Earth model. Depending on the number of students, it may also be done in groups with one person representing the group and the rest watching and taking notes.
- This activity requires a light source in the center of the room so that students can form a circle around it. The light source should be a bulb that is uncovered. A table lamp without a shade is one example.

Guiding the Discussion

It is not important which pattern students identify first. The plan is a suggestion for one possible path through the data. The order is not as important as long as the major ideas for each pattern are identified, discussed, and linked to the visualization and explanation from Lesson 7.

Repeating Demonstration of Seasons and Earth's Orbit
You may wish to repeat this activity. This time, as each stop is made, ask students, "Everyone who is having summer on their model, raise your hands." If there is disagreement over which models are having summer, have students explain their thinking.

Common Student Ideas

Shape of Earth's Orbit

A common student misconception is that Earth is closer to the sun in the summer. This would make Earth's orbit oval, and the sun would not be in the center. The Earth's orbit is elliptical, not oval.

Distance from Sun and Temperature

Some students may conclude that the Northern Hemisphere is closer to the sun during the summer because of the tilt. Technically, it is closer than the Southern Hemisphere. However, the distance by which it is closer is less than the diameter of the Earth. The change in temperature is less than 2%. This turns out to be only 5°C, which is less than the temperature change between winter and summer in most places.

Setup

Specific instructions for activity setup are embedded within the lesson.

⚠ Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

1. Activity 8.4—If there are some students in the class who are more advanced and would benefit from doing this activity individually, that would be an excellent way to allow them to move at their own pace.

Graphing the Data

2. An alternative to using the lamp would be to have a student stand in the center of the room to represent the sun. It is more effective to use an actual light source, but depending on the configuration of the classroom and accessibility to an electric outlet, using a student as the sun may be a better option.
3. Depending on students' ability to graph data, you may choose to have them work in groups to complete the graphing portion of the activity. However, each student should have a copy of the group's graph to refer to throughout the lesson.

LESSON 8

What Else Is Affecting Temperature?

TEACHING THE LESSON

Performance Expectations

Students will

- extend their previous model of sunlight and latitude to include the tilt of the Earth in orbit and explain how the light varies across the year to cause seasonal changes in climate.
- apply their model of seasonal changes in climate to explain why seasons vary in the Northern and Southern Hemispheres, and evaluate the fit of the model against yearly patterns in temperature across the globe.

Building Coherence

This lesson investigates the relationship between Earth's tilt and seasons. In the last lesson, students explained the relationship between temperature, latitude, and light intensity. In the homework for the final activity, they used their explanation to explain a visualization of temperature data for January. This lesson begins by comparing that data to data for July and realizing that their explanation from Lesson 7 does not fit the new data.

Timeframe

4–5 Class Periods

Overview

Activity 8.1

- Graph city temperature data from Lesson 7.
- Compare that data to two visualizations of average surface temperature.

Activity 8.2

Review the ideas of the Earth's rotation and revolution.

Activity 8.3

- Investigate the relationship between Earth's tilt and seasons.
- Revise the model from Activity 7.5.

Activity 8.4

Construct an explanation to answer the Driving Question: Why Is Weather Different from Place to Place?

Materials – Introduction

For the Class
- PI: July Average Surface Temperature
- PI: Comparison of July and January Visualizations

Homework Follow Up

Use PI: July Average Surface Temperature and ask students to share their ideas. Student explanations should indicate the following:

- Temperature varies by latitude.
- Hotter areas are nearer the equator.
- Cooler areas are nearer the poles.
- Light at the equator is more direct because of the shape of the Earth. It does not hit the Earth at an angle and is therefore more intense.
- More intense light means higher temperature.

Ask students the following questions:

- Does the explanation from your homework fit the visualization? (*For the most part, yes.*)
- What questions do you still have?
- Is there anything in the visualization that you cannot explain? (*Students may notice the following:*
  - o *It is cold at both poles, but the North Pole is colder than the South Pole.*
  - o *There seem to be differences between land and water at the same latitude.*
  - o *The hotter areas seem to be just south of the equator.*
  - o *There are cool spots along the west side of South America.*)

Introducing the Lesson

Students have an explanation that, for the most part, fits the visualization for January. Ask them what they think a visualization of average surface temperature for the month of July would look like based on their explanation. Keep track of students' ideas.

Possible responses may include the following.

- It would look the same because the sun heats the Earth all year, and the shape of the Earth does not change, so the intensity would be the same.
- Where we live is hotter in the summer, so the visualization should show that. For example, we live in Chicago and I know it gets hot here in the summer, so the map should show that it is hotter.
- The idea of seasons may come up at this point. If it does not, do not raise it. It will be addressed later in the lesson.

Once all ideas are shared, show PI: July Average Surface Temperature. Have students share how this visualization compares to what they thought it would show. Then, project both visualizations and have students compare the two (PI: Comparison of July and January Visualizations).

Ask students the following question:

- Does your explanation about the relationship between temperature and latitude work for the visualization of July? (*Students should point out that there is a significant change in temperature by latitude, so their previous explanation does not work.*)

Students should identify the following changes:

- The South Pole is now much colder than the North Pole.
- The band of hot temperatures is now farther north of the equator.
- Areas north of the equator are now much warmer.

Ask students if they have any other data that they can use to see if these visualizations are accurate. Students should suggest that they have temperature data from their cities in Lesson 7. Point out the location of the cities on the map. They are all at different latitudes. Suggest that they start with this city data to see if it fits the visualizations.

Materials – Activity 8.1

For the Class
- PI: City Temperature Data
- paper lantern model from Lesson 7

For Each Student
- Activity Sheet 7.1 (city temperature data)
- Activity Sheet 8.1
- (6) colored pencils* (six different colors)

*This item is not included in the kit.

Activity 8.1 – Does the City Data Match the Visualizations?

Graphing the Data

In Activity 7.1, students used the average monthly temperature data for each of the cities to determine a yearly average. Have students take out Activity 7.1 and turn to the temperature data on the last page. Ask the following questions:

- What does this chart show?
- If you are trying to find a pattern in the temperature data, is there an easier way to show the data so that the pattern would be clearer?
- How else could you represent this data?

Students should be familiar with graphs as another way to represent this kind of data. In this activity, they will graph the average monthly temperature for each of the cities in order to describe the pattern.

Students will graph the data on Activity Sheet 8.1. They should follow the instructions on the sheet. Remind them that they should use a different color pencil for each of the cities. When students have finished creating their graphs, they should answer the Making Sense questions on the last page of the activity sheet.

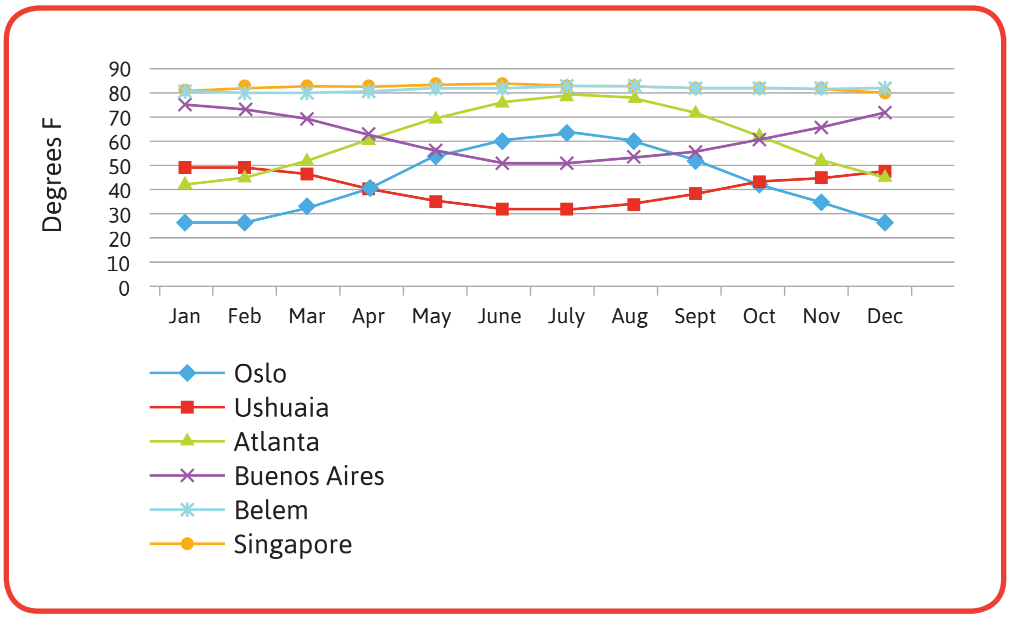
Discussion – Synthesizing

Purpose

Identify the patterns in the temperature data and compare them to the visualizations.

Have one group share their graph with the class. The class should reach consensus on what the graph should look like before moving on to the discussion. If students disagree with the graph that the first group presents, have them explain what they disagree with, and what evidence they have that the data is plotted incorrectly. The class consensus graph should be similar to the following example:

Use PI: Temperature Data so that students can use this as a basis for their discussion of the patterns. Ask them to identify one pattern they see in the data. At the top of the graph, there are two lines that overlap along the 80° line. Ask students what this pattern tells them about the temperature in these two cities.



Guiding the Discussion
It is not important which pattern students identify first. The plan is a suggestion for one possible path through the data. The order is not as important, as long as the major ideas for each pattern are identified, discussed, and linked to the visualization and explanation from Lesson 7.

Ask students to identify one pattern they see in the data. (*At the top of the graph, there are two lines that overlap along the 80° line.*)

- What does this pattern tell you about the temperature in these two cities? (*It does not change much over the course of a year.*)
- Where are these two cities (Belem and Singapore) located? (*Using the class map, students should see that these two cities are located very close to the equator.*)
- What did the visualizations show you about temperature near the equator in January and July? (*It was hot near the equator all year long.*)
- Do the temperature data for these two cities and the visualization show the same thing about the temperature in these two cities? (*Yes. The explanation from Lesson 7 said that the light from the sun hits the Earth most directly at the equator. That means the sunlight there is the most intense and temperatures are the hottest. The data from the graph shows that the two cities closest to the equator are the hottest, so the data fits with the explanation.*)

Have students continue to identify patterns. The following is a list of the possible patterns and ideas that should come out of this discussion:

There are two lines that are at their highest from June through August, and two lines that are at their lowest at that time.

- Which two cities have their highest temperatures from June through August? (*Atlanta and Oslo*)
- Where are these cities located? (*Northern Hemisphere; north of the equator*)
- Which two cities have their lowest temperatures in June through August? (*Ushuaia and Buenos Aires*)
- Where are these cities located? (*Southern Hemisphere; south of the equator*)
- Does this match with what you saw in the visualizations?

Project both visualizations and have students compare the data from the graph to the visualizations. The visualizations show that cities north of the equator have warmer temperatures June through August, and that cities south of the equator are cooler during that time.

Ask students to identify the coldest time of year for these four cities based on the graph.

- Does this match what is on the visualizations? (*Coldest temperatures for Oslo and Atlanta are from December through February, and coldest temperatures for Ushuaia and Buenos Aires are from June through August. The visualizations show this.*)

- When cities in the Northern Hemisphere are having their coldest temperatures, what is happening in the Southern Hemisphere? (*Cities there are having their warmest temperatures. It is the opposite.*)
- Does the temperature in these cities remain about the same during the year or does it vary?
- The two cities near the equator have nearly the same temperature all year. Is that true for the other places? (*no*)
- What is that variation in temperature over the course of a year called? (*seasons*)
- When it is winter in the Northern Hemisphere what season is it in the Southern Hemisphere? (*summer*)
- How do you know? (*Temperatures in the Southern Hemisphere are much warmer than in the Northern Hemisphere.*)

At this point, students should be able to connect the data on the graph to what they see in the visualization and see that they agree. Return to the paper lantern model of the Earth from Lesson 7. Position the model so that it is directly opposite the light source as it was in Activity 7.3. Remind students that in Lesson 7, they determined the following:

- Light from the sun strikes spots on the Earth that are at the same latitude in the Southern and Northern Hemispheres at the same angle.
- The shape of the Earth affects the angle at which sunlight strikes the Earth.
- Sunlight strikes the Earth most directly at the equator.
- The farther away from the equator a place is, the less direct the sunlight.
- The angle at which light hits the Earth affects its intensity.
- The more intense the light, the higher the temperature of that place.

Ask students the following: "Do those ideas from your explanation in Lesson 7 explain what you see in your graph?" (*Students should be able to reason that if it were just the shape of the Earth, temperatures both north and south of the equator would be the same all year.*)

Students are left with two questions:

- What causes the temperature differences over a year that create seasons?
- Why are seasons the opposite in the Northern and Southern Hemispheres?

Record these questions on the DQB, so students can track what they are trying to answer in the next activity.

Brainstorm with students their ideas about the answers to these questions and record them.

What else do you know about Earth that might affect the temperature? (*Possible ideas might include day and night; seasons; the fact that the Earth revolves around the sun, rotates on its axis, or spins; and the idea of tilt.*)

It is not important that students have an understanding of these ideas at this time. In the next activity, students will investigate the ideas of rotation and revolution. Tilt will be investigated in Activity 8.3, and it is not necessary to raise it as a possibility here if students do not bring it up.

Materials – Activity 8.2

For the Class

- (1) lamp without shade (This is used to represent the sun. The bulb needs to be exposed on all sides. A table lamp with the shade removed works well.)

For Each Student

- (1) Styrofoam ball (3" diameter; if activity is done in groups, one per group)
- markers*: black, blue, green, yellow, and red
- (1) pencil*
- Activity Sheet 8.2

*This item is not included in the kit.

Activity 8.2 – How Does the Earth Move?

Setting Up the Earth Model

Students left the last activity with two unanswered questions and some possible ideas for answers. Refer to the two questions on the DQB and the ideas that students brainstormed. In this activity, students will use a ball model of the Earth to investigate the Earth's rotation on its axis and revolution around the sun to see if those movements can answer their questions.

Distribute materials and guide students through the setup of their models. They should be given time to fill in their activity sheets as the activity progresses. The directions for setting up their models are on their activity sheets.

Have students begin by drawing a black line around the middle of their Styrofoam ball to represent the equator.

Complete the remaining steps. Be sure to question students about what the markings on the ball represent. (Refer to the questions that follow.)

- Mark the North and South Poles with a red dot.
- Approximately halfway between the equator and the North Pole, place a green dot.
- Between the green dot and the North Pole, place a blue dot. This dot should be closer to the pole than the green dot. The three dots (red, blue, and green) should be in a line.
- Halfway between the equator and the South Pole, place another green dot.
- Between the green dot and the South Pole, place a blue dot.
- Place two yellow dots just above and just below the equator.

When students finish, their models should look like the following representation.

The chart on the first page of the activity sheet asks students to make the connection between the location of the dots on their model and the latitude of the cities they have been studying. Using the map where the cities are plotted, make sure students understand that the cities do not all line up along the same longitude. They are looking at latitude, because the data showed that cities at the same latitude (whether north or south of the equator) had approximately the same temperature. Longitude was not a factor. In this model, the cities are lined up along the same longitude so that it is easier to compare the variation caused by latitude. Allow students a few minutes to fill in the chart and then review it with them.

The answers are as follows:

North of the Equator:

- yellow = Singapore
- green = Atlanta
- blue = Oslo

South of the Equator:

- yellow = Belem
- green = Buenos Aires
- blue = Ushuaia

Have students push the pencil into the ball at the South Pole.

If the pencil were long enough and could extend out the point where the North Pole is, what would this represent? (*Earth's axis*)

Students may be familiar with this term from previous science classes.

They should understand the following key ideas:

- Earth's axis is an imaginary line that runs from the North Pole to the South Pole through the center of Earth.
- Earth rotates one full turn around its axis each day. This is why people experience day and night. Place a lamp without a shade in the center of the room to represent the sun.

Investigating Earth's Movements Using the Model

Students should form a circle around the sun, holding their models by the pencil. They should keep the pencil perpendicular to the floor holding their model vertically. Have all students orient their models so that the dots are directly facing the sun.

- What time of day would people standing on Earth where the dots are be experiencing now? (The time of day would be *noon*.)
- How do you know? (*They are directly facing the sun*.)

Have students spin their model 180° so that the dots are now facing away from the sun, opposite from where they started. They should rotate their Earth in a counterclockwise direction.

- What time of day would it be where the dots are not located? How do you know? (*It would be night because no light is reaching the dots*.)
- What is this spinning of the Earth called? (*It is called rotation*.)
- What does this create? (*It creates day and night*.)
- Why is it night on the side of the Earth that is facing away from the sun? (*The sun's rays are blocked by the Earth and cannot reach the side that is facing away from the sun*.)

Students should understand that light travels in a straight path. Light from the sun cannot curve around the Earth to reach the opposite side. This concept was explored in the IQWST PS1 unit.

Answer Questions 1, 2, and 3 in Part 1 on the activity sheet.

- In this model, do all parts of the Earth receive the same number of hours of light in a day? (*yes*)
- Does that agree with your data on hours of daylight from Activity 7.2? (*The data showed that the number of hours of daylight that a location received varied each month over the course of the year. However, during an entire year, all places on the Earth receive the same number of hours of sunlight*.)
- If all places got the same number of daylight hours each day like in this model, would the number of hours of daylight each month vary?
- Does the rotation of the Earth on its axis creating day and night answer your two questions? If not, what can rotation not explain? (*In this model, rotation creates day and night with all places on the globe receiving the same number of hours of daylight each day. This does not fit the data from 7.2 that showed the hours of daylight varied by month. It also does not explain why the Northern and Southern Hemispheres have opposite temperatures at the same time of year.)*

- If day and night cannot answer your questions, what else do you want to investigate?
- What other movement besides rotating on its axis does the Earth make?
- In Lesson 7, you looked at data over the course of a year. What is a year? (*Some students may offer the idea of the Earth moving around the sun, and that it takes a year for it to happen. If "revolve around the sun" does not come up, suggest it here.*)
- How long does it take Earth to revolve around the sun one time? (*Students should know that it takes the Earth one year to complete one orbit around the sun.*)

Students will model Earth revolving around the sun to see if this movement can answer their questions:

1. What causes the temperature differences that create seasons?
2. Why are the seasons opposite in the Northern and Southern Hemispheres?

Have students fill in the Prediction section in Part 2 of their activity sheet. This asks them to draw what they think Earth's orbit looks like and explain why they think it looks that way. After completing their predictions, have students share their ideas about the shape of the Earth's orbit by drawing them on the board. Be sure to get all ideas posted. Students will revisit this prediction after they complete Activity 8.3.

Turn on the light in the center of the room. The main source of light in the room should be the lamp. You may need to turn off the lights and pull down the shades. Have students form a circle around the light. Position the circle around the lamp, so that the sun (lamp) is in the center.

- What does this circle represent? (*Earth's orbit around the sun*)
- Which way should you face in order to move around the sun counterclockwise? (*Tell students that the Earth orbits the sun in a counterclockwise direction. This is the same direction that the Earth spins on its axis.*)

Students should hold their models vertically using the pencil. Remind them that the Earth is making two movements at the same time: revolving on its axis and rotating around the sun.

Have students begin to spin their globes and then move halfway around the lamp representing the sun.

- Does any part of your Earth stay in the light longer than another as you move around the sun? (*no*)
- What do you think would happen if you changed the shape of the orbit?
- Have students change the shape of the orbit to match some of the suggested possibilities from their predictions. For each new orbit shape, ask them if any part of the Earth stays in the light longer. Students should see that all parts are receiving the same amount of light no matter what shape the orbit is, because the Earth is being held vertically.

Have students complete the Making Sense questions on their activity sheets.

Making Sense of the Investigation

Do any of these orbits explain why there are seasons? (*Some students may suggest that the orbit that shows the sun closer to the Earth at one time of year explains summer and winter.*)

Remind students that there are two questions they are trying to answer. Ask if any of the orbits that have been suggested can answer their question about why the seasons (temperatures) are opposite in the Northern and Southern Hemispheres.

Students should be able to state that the light from the sun would be the same at 30°N latitude as it would be at 30°S. Cities such as Oslo and Ushuaia would be receiving about the same amount of light and the same intensity of light, so their temperatures should not be very different.

Let students know the following about Earth's orbit:

- Earth's orbit is almost a circle around the sun.
- Draw the Earth's orbit on the board with the orbit being elliptical (but almost a perfect circle) and the sun slightly off from the center. Compare this to the drawings students did. If there are students' drawings that are approximately correct, leave them posted on the DQB. If there are none, post your drawing.
- The Earth is slightly closer to the sun in January.
- The farthest the Earth is from the sun is 152 million miles. The closest is 147 million miles. Let students know that the percentage change in distance from closest to farthest point from the sun is only 3%. Link this difference to the local temperature students experience. Ask the following questions:
    - o How hot does it usually get here in the summer?
    - o How cold is it in the winter?
    - o Is that more than a 3% difference?

At the end of this activity, students should understand the following.

- Earth rotates on its axis once every 24 hours, creating day and night.
- Earth revolves around the sun once a year.
- Earth's orbit is almost a circle, and its distance from the sun does not vary much over the course of a year.
- If Earth is straight on its axis and making these two movements, students still cannot answer their questions.

- Do these four ideas help you answer your questions? (*In Activity 6.1, students learned that rotation produces day and night, but still cannot explain seasons. In Activity 6.2, they learned that revolution around the sun occurs once a year but cannot answer both questions.*)
- Does the shape of the Earth's orbit answer both questions? (*If the Earth were closer to the sun in the summer, and farther away in the winter, that could explain seasons, but it does not work because it cannot explain why seasons are opposite in the Northern and Southern Hemispheres.)*
- What ideas do you have about what could be causing the differences?
- Do you think your model is an accurate representation of what is happening with the Earth? Why?
- What do you think you could change about the model to make it more accurate? (*Some students may suggest that the Earth should not be vertical but rather should be tilted. In previous science classes, students may have heard that the Earth is tilted.)*
- What do you mean by *tilted*, and why do you think it is important?

In the next activity, students will use this same model, only with a tilted Earth to see if that can answer both of their questions about seasons.

Materials – Activity 8.3

For the Class
- (1) lamp without shade (from Activity 8.2)

For Each Student
- Styrofoam ball Earth model (from Activity 8.2)
- Activity Sheet 8.3

Activity 8.3 – Does a Tilted Earth Explain the Seasons?

What Is Tilt?

Students are trying to answer the following two questions:

- Why does temperature vary over the course of the year causing seasons?
- Why are seasons in the Northern Hemisphere opposite those in the Southern Hemisphere?

At the end of Activity 8.2, students suggested some ideas about what else they could test with their model. It is assumed that tilt will be on the list. If it is not, prompt students to add it by asking if anyone has ever heard of the Earth being tilted on its axis. In this activity, students will investigate what will happen if the Earth is tilted rather than being vertical. If the word *tilt* is already on the list, ask students what it means for the Earth to be tilted on its axis.

Have all students tilt the North Pole of their models toward the sun and spin their models. Ask the following questions:

- Do all the dots (cities) have day and night? (*yes*)
- Which cities have longer days? Shorter?
- Can someone show me what that would look like using your model? (*Northern Hemisphere cities have longer days; Southern Hemisphere cities have shorter ones.*)
- How many hours of daylight would there be at the North Pole? South Pole? (*North Pole receives 24 hours of daylight; South Pole receives 24 hours of darkness.)*
- What season is it in the blue and green dot cities in the Northern Hemisphere? (*The season is summer.*)
- Is the temperature the same in both cities? Why? (*The blue dot city receives more hours of daylight and would be warmer than the green dot city. The more hours of daylight a place receives, the higher the temperature. Data from Activity 7.2 show this.)*
- In your model, you have the Northern Hemisphere tilted toward the sun. Is this how it is all year? How do you know?
- What happens to cause the seasons to change during the year?

At this point, students may suggest that the tilt changes, so that sometimes the North Pole points toward the sun and sometimes the South Pole does. This changing direction of the poles is a common student misconception about what causes seasons.

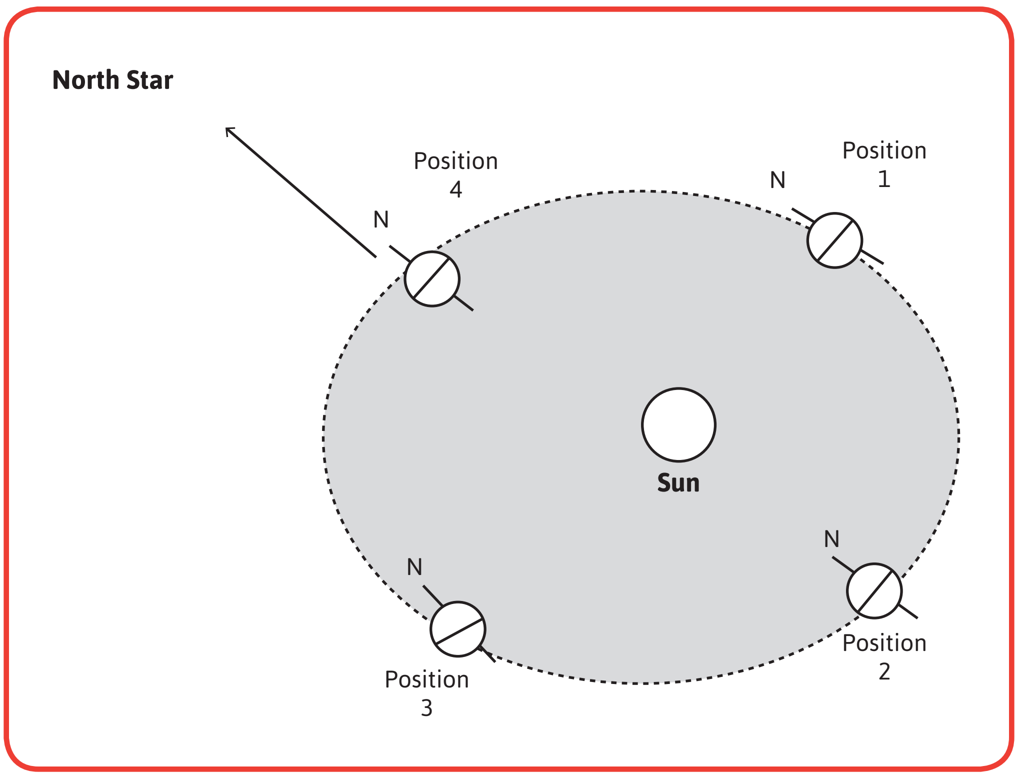
- Have a student demonstrate what this would look like.
- Does the Earth rock back and forth like that? (*Tell students that as the Earth moves around the sun in its orbit, the North Pole is always pointing at the North Star. This tilts the Earth's axis at an angle of 23.5°.*)

Investigating Tilt Using the Earth Model

Pick a spot in the classroom to represent the North Star. This can be a clock or a poster mounted high on the wall. (You can also use a corner of the room where the wall meets the ceiling.) Have students tilt the North Pole of their model toward the North Star. Go around the circle to check student positions. They should be positioned as follows:

- Students standing between the sun and the North Star should have their North Poles facing away from the sun.
- Students standing on the opposite of the "orbit" should have their North Poles facing toward the sun.
- Students standing midway between these places in the orbit should have their North Pole facing somewhat sideways.

See the following model.



Once students have their models positioned correctly, move around the orbit and use the following prompts.

Reminder: Students may need to be reminded that "tilted toward the sun" does not mean that the North Pole is pointed directly at the sun. It means that the Northern Hemisphere is facing in the direction of the sun at an angle. Begin with the place in the circle (orbit) where the Northern Hemispheres on student models are facing toward the sun.

- When the Earth is in this part of its orbit, which hemisphere is facing toward the sun? (*It is the Northern Hemisphere*.)
- What season are the blue and green cities on your model having? Why? (*It is summer because they are facing the sun more directly and are getting more intense light. They are also experiencing more hours of daylight.*)
- Is it the same season for the blue and green cities in the Southern Hemisphere? Why? (*The Southern Hemisphere is having winter. It is facing away from the sun and gets less intense light and fewer hours of daylight light.*)

Move around the "orbit," making a total of four stops. Repeat these questions at each point in the orbit.

You may wish to repeat this activity. This time, as each stop is made, ask students, "Everyone who is having *summer* on their model, raise your hands." If there is disagreement over which models are having *summer,* have students explain their thinking.

When students seem able to demonstrate their understanding of tilt and how it affects seasons, have students complete the model on the activity sheet that asks them to draw and label a model of the Earth's orbit, tilt, and seasons. This should diagram what they just physically demonstrated in class.

Discussion – Making Sense

Purpose

Connect the ideas of tilt and seasons.

When students have finished, have someone put their model on the board (or project it using a document cam).

Using the student model as a focus for the discussion, prompt students to think about the following:

- Does the model show the shape of the Earth's orbit?
- Is there anything about the shape you would change? Why?
- Does the model show Earth in the correct position for winter in the Northern Hemisphere? Why?
- How would you change it? Why?
- What about summer in the Northern Hemisphere? Why?
- What would you change, and why?
- Are spring and fall identified correctly?

Continue to press students for understanding until the class seems to be able to explain the model and agree on it. Post the final model of the seasons on the DQB.

Remind students of what they learned about light in Lesson 7:

- The temperature on Earth varies by latitude.
- The light intensity varies by latitude and corresponds to temperature (i.e., greater intensity equals higher temperature.)
- The angle at which light hits the earth affects intensity (more spread out, less intense) and therefore temperature.
- The sun hits the Earth most directly at the equator, making the light more intense. This is where the highest temperatures were.

Use the light source and lantern from Lesson 7 to show students the following:

- The shape of the Earth affects light intensity and temperature.
- The light at the equator was more intense and the temperatures were highest.

Lead In

- Would tilting the lantern model affect intensity? How?

Tilt the lantern so that the North Pole is pointed away from the light source. Have students discuss in their groups what they think would happen to the intensity of the light in the Northern Hemisphere and the Southern and why. Give students about five minutes to discuss their ideas. Then, bring the class together and have them share their ideas. After all ideas have been shared, ask them if they can think of a way they could test their ideas. Could you measure the intensity using the light sensor? Enlist the help of two students and measure the light intensity at the equator and in two spots both north and south of the equator while the lantern is tilted. Students should see the following.

- The equator is no longer the hottest. Ask where the hottest latitude is now.
- The two spots north of the equator had much less intense light than the two spots south of the equator.

Suggested Prompts

- How do these readings compare to the data from Activity 7.3?
- How would those intensity readings affect the temperature of cities north of the equator? (*colder*)
- What about cities south of the equator? (*warmer*)
- What season would it be north of the equator? (*winter*)
- What season would it be south of the equator? (*summer*)

Have students return to the activity sheet and answer the final question. This asks for a scientific explanation to answer the two questions students have been working on throughout this lesson. These are the two questions that students have been trying to answer:

- What causes the temperature differences that cause seasons?
- Why are seasons opposite in the Northern and Southern Hemispheres?

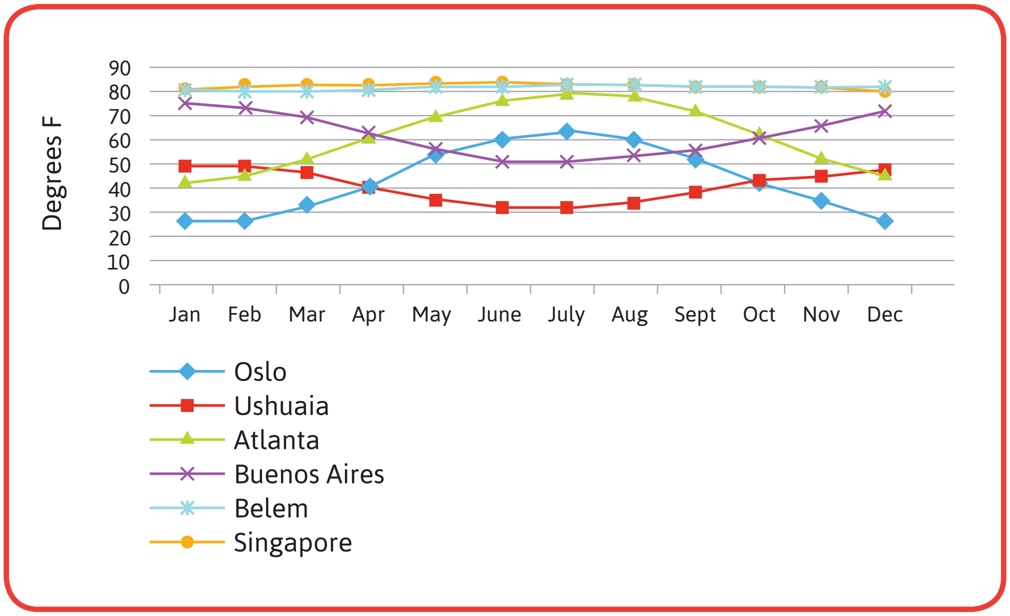
Discussion – Synthesizing

Purpose

Bring together the ideas about light, temperature, tilt, and seasons.

Create a two-column chart that lists the big ideas from Lessons 7 and 8 and the evidence that supports them that students have collected.

BIG IDEAS	
(Scientific Principles)	Evidence that Supports the Principle



At the end of this activity, students should understand the following.

1. The intensity of the light reaching the Earth at different latitudes varies because of the Earth's shape.
   - Evidence—Lantern activity where light intensity was measured at various latitudes, and the readings, showed the light was less intense the farther away from the equator a site was.
2. The difference in intensity is because the same amount of light is being spread over a larger area.
   - Evidence—Graph paper activity where the flashlight was tilted and the light covered more squares of the graph paper.
3. Light intensity is greatest at the equator.
   - Evidence—Lantern activity which showed the light sensor had the highest readings at the equator.
4. The more intense the light, the higher the temperature.
   - Evidence—City data showed that the cities close to the equator had higher temperatures than the cities farther away.

5. Because Earth is tilted, there are seasons. (This explains seasons but not why the hemispheres are different.)
   - Evidence—Lantern activity showed that if the Earth were vertical, the cities at the same latitude north and south of the equator would get the same intensity of light and their temperatures should be the same all year. Data from cities showed this was not true.
   - Evidence—Class modeling of Earth's movements. Revolving around the sun when Earth was not titled did not make any difference in the Northern and Southern Hemispheres.
   - Evidence—The tilted Earth model also showed that during the summer, the areas north of the equator got more hours of daylight. This means more light energy can be transferred, and they would be warmer.
6. The Earth is tilted so that the North Pole always is pointed toward the North Star. This keeps the Earth at the same tilt all year long. The way the Earth is tilted, and the fact that it orbits the sun, is what cause seasons to be different in the Northern and Southern Hemispheres.
   - Evidence—Class physical models showed this. At one time of year, the Northern Hemisphere was facing the sun and experiencing summer. The light that was hitting the Northern Hemisphere would be more direct and more intense causing higher temperatures. At the same time, the Southern Hemisphere was facing away from the sun, and the Southern Hemisphere was experiencing winter. The light would be less direct and less intense, so temperatures would be lower.

The class should reach consensus on these ideas before moving on.

In this lesson, students have explained a complex phenomenon and will now apply those ideas to answer the final question on the DQB. Remind students that they have not answered the second part of the Driving Question: Why Is Weather Different from Place to Place? In the next activity, they will explain why the weather is not the same in two of their case study cities.

Activity 8.4 – Why Is the Temperature Not the Same Everywhere?

Comparing Two Cities and Constructing an Explanation

Students still have not answered the second part of the Driving Question: Why Is Weather Different from Place to Place? In the last activity, students explained the answers to two questions that should help them answer the final part of the Driving Question. In this activity, students will work in groups to use the data about two of the case study cities, along with evidence gathered in Lessons 7–8, to write an explanation that will answer the question.

Using the map in the room (or on students' activity sheets), review the location of each of the cities on the map. Ask students what kind of data they have for each of the cities:

- latitude/longitude
- average monthly temperature
- hours of daylight by month and total for year

Then ask what kind of data they have collected in class:

- light intensity using the lantern
- effect of angle on light intensity (flashlight and graph paper)

Ask if they have anything else that will help answer the question:

- model on worksheet of Earth's orbit
- model on worksheet of Earth's position at different seasons

Explain to students that they will work in groups to complete this activity. Each group will choose two cities from the six case study cities. One city should be from the Northern Hemisphere and one from the Southern Hemisphere. It does not matter which two cities they pair together.

Put students into groups of three or four. They should first make sure that they have all of the data and worksheets that they will need. Then, have them choose their cities. There are nine possible combinations, so it is possible that no two groups would have the same pair. However, if groups do want to use the same pair of cities, this would be fine and would give them an opportunity to evaluate each others' ideas before writing their final explanation. Each student should then write his or her own explanation to answer the Driving Question: Why Is Weather Different from Place to Place?

Students should be given 1–2 days to organize their data and ideas and write their explanations. They then can meet with their group to compare ideas and evidence.

After the explanations are complete, have students share some of their explanations with the class. After a student has read his or her explanation, have others share why they agree or disagree.

- Do you agree with the evidence they used?
- Does the evidence support the big ideas?
- Is there anything you would add to this explanation? All explanations do not have to be shared.

Wrapping Up the Lesson

Suggested Prompts

- Which model helps you answer the question about why weather is not the same from day to day?
- What evidence do you have to support your answer?
- Which model explains why the weather is not the same everywhere? How?

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