In this chapter, we explore the ways reading, writing, speaking, and listening are interwoven in effective science instruction at the secondary level. To engage fully in the enterprise of science and engineering, students must record and communicate observations and explanations, and read about and discuss the discoveries and ideas of others. This becomes increasingly challenging at the secondary level. Texts become more complex; writing requires fluency of academic language, including domain-specific vocabulary. Here we identify strategies that support sense making. The active investigations, student science notebooks, FOSS Science Resources readings, multimedia, and formative assessments provide rich contexts in which students develop and exercise thinking processes and communication skills. Students develop scientific literacy through experiences with the natural world around them in real and authentic ways and use language to inquire, process information, and communicate their thinking about the objects, organisms, and phenomena they are studying. We refer to the acquisition and building of language skills necessary for scientific literacy as science-centered language development.
Language plays two crucial roles in science learning: (1) it facilitates the communication of conceptual and procedural knowledge, questions, and propositions (external; public), and (2) it mediates thinking, a process necessary for understanding (internal; private). These are also the ways scientists use language: to communicate with one another about their inquiries, procedures, and understandings; to transform their observations into ideas; and to create meaning and new ideas from their work and the work of others. For students, language development is intimately involved in their learning about the natural world. Active-learning science provides a real and engaging context for developing literacy; language-arts skills and strategies support conceptual development and scientific and engineering practices. For example, the skills and strategies used for reading comprehension, writing expository text, and oral discourse are applied when students are recording their observations, making sense of science content, and communicating their ideas. Students’ use of language improves when they discuss, write, and read about the concepts explored in each investigation.

We begin our exploration of science and language by focusing on language functions and how specific language functions are used in science to facilitate information acquisition and processing (thinking). Then we address issues related to the specific language domains—speaking and listening, writing, and reading. Each section addresses

- how skills in that domain are developed and exercised in FOSS science investigations;
- literacy strategies that are integrated purposefully into the FOSS investigations; and
- suggestions for additional literacy strategies that both enhance student learning in science and develop or exercise academic-language skills.

Following the domain discussions is a section on science-vocabulary development, with scaffolding strategies for supporting all learners. The last section covers language-development strategies specifically for English learners.

**NOTE**
The term *English learners* refers to students who are learning to understand English. This includes students who speak English as a second language and native English speakers who need additional support to use language effectively.
THE ROLE OF LANGUAGE IN SCIENTIFIC AND ENGINEERING PRACTICES

Language functions are the purpose for which speech or writing is used and involve both vocabulary and grammatical structure. Understanding and using language functions appropriately is important in effective communication. Students use numerous language functions in all disciplines to mediate communication and facilitate thinking (e.g., they plan, compare, discuss, apply, design, draw, and provide evidence).

In science, language functions facilitate scientific and engineering practices. For example, when students are collecting data, they are using language functions to identify, label, enumerate, compare, estimate, and measure. When students are constructing explanations, they are using language functions to analyze, communicate, discuss, evaluate, and justify.

*A Framework for K–12 Science Education* (National Research Council 2012) states that “Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing the practices for themselves.” Each of these scientific and engineering practices uses multiple language functions. Often, these language functions are part of an internal dialogue weighing the merits of various explanations—what we call thinking. The more language functions with which we are facile, the more effective and creative our thinking can be.

The scientific and engineering practices are listed below, along with a sample of the language functions that are exercised when students are effectively engaged in that practice. (Practices are bold; language functions are italic.)

**Asking questions and defining problems**

- *Ask* questions about objects, organisms, systems, and events in the natural and human-made world (science).
- *Ask* questions to define and clarify a problem, determine criteria for solutions, and identify constraints (engineering).

**Planning and carrying out investigations**

- *Plan* and conduct investigations in the laboratory and in the field to gather appropriate data (describe procedures, determine observations to record, decide which variables to control) or to gather data essential for specifying and testing engineering designs.

**Examples of Language Functions**

Analyze
Apply
Ask
Clarify
Classify
Communicate
Compare
Conclude
Construct
Critique
Describe
Design
Develop
Discuss
Distinguish
Draw
Enumerate
Estimate
Evaluate
Experiment
Explain
Formulate
Generalize
Group
Identify
Infer
Interpret
Justify
Label
List
Make a claim
Measure
Model
Observe
Organize
Plan
Predict
Provide evidence
Reason
Record
Represent
Revise
Sequence
Solve
Sort
Strategize
Summarize
Synthesize
Analyzing and interpreting data

- Use a range of tools (numbers, words, tables, graphs, images, diagrams, equations) to organize observations (data) in order to identify significant features and patterns.

Developing and using models

- Use models to help develop explanations, make predictions, and analyze existing systems, and recognize strengths and limitations of the models.

Using mathematics and computational thinking

- Use mathematics and computation to represent physical variables and their relationships.

Constructing explanations and designing solutions

- Construct logical explanations of phenomena, or propose solutions that incorporate current understanding or a model that represents it and is consistent with the available evidence.

Engaging in argument from evidence

- Defend explanations, formulate evidence based on data, examine one’s own understanding in light of evidence offered by others, and collaborate with peers in searching for explanations.

Obtaining, evaluating, and communicating information

- Communicate ideas and the results of inquiry—orally and in writing—with tables, diagrams, graphs, and equations and in discussion with peers.

Research supports the claim that when students are intentionally using language functions in thinking about and communicating in science, they improve not only science content knowledge, but also language-arts and mathematics skills (Ostlund, 1998; Lieberman and Hoody, 1998). Language functions play a central role in science as a key cognitive tool for developing higher-order thinking and problem-solving abilities that, in turn, support academic literacy in all subject areas.
Here is an example of how an experienced teacher can provide an opportunity for students to exercise language functions in FOSS. In the **Planetary Science Course**, one piece of content we expect students to have acquired by the end of the course is

- The lower the angle at which light strikes a surface, the lower the density of the light energy.

The scientific practices the teacher wants the class to focus on are developing and using models and constructing explanations.

The language functions students will exercise while engaging in these scientific practices include comparing, modeling, analyzing, and explaining. The teacher understands that these language functions are appropriate to the purpose of the science investigation and support the *Common Core State Standards for English Language Arts and Literacy in Science* (CCSS), in which grades 6–8 students will “write arguments focused on discipline-specific content . . . support claim[s] with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic” (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010).

- Students will compare the area covered by the same beam of light (from a flashlight) at different angles to explain the relationship between the angle and density of light energy.

The teacher can support the use of language functions by providing structures such as sentence frames.

- As ______, then ______.
  
  *As the angle increases, then the light beam becomes smaller and more circular.*

- When I changed ______, then ______.
  
  *When I changed the angle of the light beam, then the concentration of light hitting the floor changed.*

- The greater/smaller ______, the ______.
  
  *The smaller the angle of the light beam, the more the light beam spread out.*

- I think ______, because ______.
  
  *I think the smaller spot of light receives more energy than the larger spot because the light concentration is greatest when light shines directly down on a surface and there is no beam spreading.*
SPEAKING AND LISTENING DOMAIN

The FOSS investigations are designed to engage students in productive oral discourse. Talking requires students to process and organize what they are learning. Listening to and evaluating peers’ ideas calls on students to apply their knowledge and to sharpen their reasoning skills. Guiding students in instructive discussions is critical to the development of conceptual understanding of the science content and the ability to think and reason scientifically. It also addresses a key middle school CCSS Speaking and Listening anchor standard that students “engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on [grade-level] topics, texts, and issues, building on others’ ideas and expressing their own clearly.”

FOSS investigations start with a discussion—a review to activate prior knowledge, presentation of a focus question, or a challenge to motivate and engage active thinking. During the active investigation, students talk with one another in small groups, share their observations and discoveries, point out connections, ask questions, and start to build explanations. The discussion icon in the sidebar of the Investigations Guide indicates when small-group discussions should take place.

Throughout the activity, the Investigations Guide indicates where it is appropriate to pause for whole-class discussions to guide conceptual understanding. The Investigations Guide provides you with discussion questions to help stimulate student thinking and support sense making. At times, it may be beneficial to use sentence frames or standard prompts to scaffold the use of effective language functions and structures. Allowing students a few minutes to write in their notebooks prior to sharing their answers also helps those who need more time to process and organize their thoughts.

On the following pages are some suggestions for providing structure to those discussions and for scaffolding productive discourse when needed. Using the protocols that follow will ensure inclusion of all students in discussions.
Partner and Small-Group Discussion Protocols
Whenever possible, give students time to talk with a partner or in a small group before conducting a whole-class discussion. This provides all students with a chance to formulate their thinking, express their ideas, practice using the appropriate science vocabulary, and receive input from peers. Listening to others communicate different ways of thinking about the same information from a variety of perspectives helps students negotiate the difficult path of sense making for themselves.

**Dyads.** Students pair up and take turns either answering a question or expressing an idea. Each student has 1 minute to talk while the other student listens. While student A is talking, student B practices attentive listening. Student B makes eye contact with student A, but cannot respond verbally. After 1 minute, the roles reverse.

Here’s an example from the Chemical Interactions Course. After reviewing the results of eight reactions recorded in their notebooks, you ask students to pair up and take turns sharing which two substances they think constitute the mystery mixture and their reasons for selecting those two. The language objective is for students to compare their test results and make inferences based on their observations and what they know about chemical reactions (orally and in writing). These sentence frames can be written on the board to scaffold student thinking and conversation.

- I think the two substances in the mystery mixture are _____ and ______.
- My evidence is ______.

**Partner parade.** Students form two lines facing each other. Present a question, an idea, an object, or an image as a prompt for students to discuss. Give them 1 minute to greet the person in front of them and discuss the prompt. After 1 minute, call time. Have the first student in one of the lines move to the end of the line, and have the rest of the students in that line shift one step sideways so that everyone has a new partner. (Students in the other line do not move.) Give students a new prompt to discuss for 1 minute with their new partners. This can also be done by having students form two concentric circles. After each prompt, the inner circle rotates.

For example, when students are just beginning the Earth History Course investigation on igneous rock, you may want to assess prior knowledge about Earth’s layers. Give each student a picture from an assortment of related images such as volcanoes, magma, a diagram of Earth’s layers, crystals, and so forth, and have students line up facing
each other in two lines or in concentric circles. For the first round, ask, “What do you observe in the image on your card?” For the second round, ask, “What can you infer from the image?” For the third round, ask, “What questions do you have about the image?” The language objective is for students to describe their observations, infer how the landform formed, and reflect upon and relate any experiences they may have had with a similar landform. These sentence frames can be used to scaffold student discussion.

- I observe ______, ______, and ______.
- I think this shows ______ because ______.
- I wonder ______.

**Put in your two cents.** For small-group discussions, give each student two pennies or similar objects to use as talking tokens. Each student takes a turn putting a penny in the center of the table and sharing his or her idea. Once all have shared, each student takes a turn putting in the other penny and responding to what others in the group have said. For example,

- I agree (or don’t agree) with ______ because ______.

Here’s an example from the Diversity of Life Course. In their notebooks, students have recorded the amount of water lost from their vials containing celery with and without leaves. They discover a discrepancy in the amount of water lost and the mass of the celery. Where did the water go? Students are struggling to form an explanation. The language objective is for students to compare their results and infer that there is a relationship between the amount of water lost and the number of leaves the celery has. You give each student two pennies, and in groups of four, they take turns putting in their two cents. For the first round, each student answers the question “Where did the water go?” They use the frame

- I think the water ______.
- My evidence is ______.

On the second round, each student states whether he or she agrees or disagrees with someone else in the group and why, using the sentence frame.
Whole-Class Discussion Supports

The whole-class discussion is a critical part of sense making. After students have had the active learning experience and have talked with their peers in pairs and/or small groups, sharing their observations with the whole class sets the stage for developing conventional explanatory models. Discrepant events, differing results, and other surprises are discussed, analyzed, and resolved. It is important that students realize that science is a process of finding out about the world around them. This is done through asking questions, testing ideas, forming explanations, and subjecting those explanations to logical scrutiny, that is, argumentation. Leading students through productive discussion helps them connect their observations and the abstract symbols (words) that represent and explain those observations. Whole-class discussion also provides an opportunity for you to interject an accurate and precise verbal summary as a model of the kind of thinking you are seeking. Facilitating effective whole-class discussions takes skill, practice, a shared set of norms, and patience. In the long run, students will have a better grasp of the content and will improve their ability to think independently and communicate effectively.

Norms should be established so that students know what is expected during science discussions.

- Science content and practices are the focus.
- Everyone participates (speaking and listening).
- Ideas and experiences are shared, accepted, and valued. Everyone is respectful of one another.
- Claims are supported by evidence.
- Challenges (debate and argument) are part of the quest for complete understanding.

A variety of whole-class discussion techniques can be introduced and practiced during science instruction that address the CCSS Speaking and Listening standards for students to “present claims and findings [e.g., argument, narrative, informative, summary presentations], emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.”

For example, during science talk, students are reminded to practice attentive listening, stay focused on the speaker, ask questions, and respond appropriately. In addition, in order for students to develop and practice their reasoning skills, they need to know the language forms...
and structures and the behaviors used in evidence-based debate and argument, such as using data to support claims, disagreeing respectfully, and asking probing questions (Winokur and Worth, 2006).

Explicitly model the language structures appropriate for active discussions, and encourage students to use them when responding to guiding questions and during science talks.

**Sentence frames.** These samples can be posted as a scaffold as students develop their reasoning and oral participation skills.

- I think ______, because ______.
- I predict ______, because ______.
- I claim ______; my evidence is ______.
- I agree with ______ that ______.
- My idea is similar/related to ______’s idea.
- I learned/discovered/heard that ______
- <Name> explained ______ to me.
- <Name> shared ______ with me.
- We decided/agreed that ______.
- Our group sees it differently, because ______.
- We have different observations/results. Some of us found that ______. One group member thinks that ______.
- We had a different approach/idea/solution/answer: ______.

**Guiding questions.** The Investigations Guide provides questions to help concentrate student thinking on the concepts introduced in the investigation. Guiding questions should be used during the whole-class discussion to facilitate sense making. Here are some other open-ended questions that help guide student thinking and promote discussion.

- What did you notice when ______?
- What do you think will happen if ______?
- How might you explain ______? What is your evidence?
- What connections can you make between ______ and ______?
Whole-Class Discussion Protocols

The following tried-and-true participation protocols can be used to enhance whole-class discussions. The purpose of these protocols is to increase meaningful participation by giving all students access to the discussion, allowing students time to think (process), and providing a context for motivation and engagement.

**Think-pair-share.** When asking for a response to a question posed to the class, give students a minute to think silently. Then, have students pair up with a partner to exchange thoughts before you call on a student to share his or her ideas with the whole class.

**Pick a stick.** Write each student’s name on a craft stick, and keep the sticks handy in a cup at the front of the room. When asking for responses, randomly pick a stick, and call on that student to start the discussion. Continue to select sticks as you continue the discussion. Your name can also be on a stick in the cup. To keep students on their toes, put the selected sticks into a smaller cup hidden inside the larger cup out of view of students. That way students think they may be called again.

**Whip around.** Each student takes a quick turn sharing a thought or reaction. Questions are phrased to elicit quick responses that can be expressed in one to five words (e.g., “Give an example of a stored-energy source.” “What does the word heat make you think of?”).

**Commit and toss.** Have students write a response to a question or prompt on a loose piece of paper (Keeley, 2008). Next, tell everyone to crumple up the paper into a ball and toss it to another student. Continue tossing for a few minutes, and then call for students to stop, grab a ball, and read the response silently. Responses can then be shared with partners, small groups, or the whole class. This activity allows students to answer anonymously, so they may be willing to share their thinking more openly.

**Group posters.** Have small groups design and graphically record their investigation data and conclusions on a quickly generated poster to share with the whole class.
WRITING DOMAIN

Information processing is enhanced when students engage in informal writing. When allowed to write expressively without fear of being scorned for incorrect spelling or grammar, students are more apt to organize and express their thoughts in different ways that support their own sense making. Writing in science promotes use of science and engineering practices, thereby developing a deeper engagement with the science content. This type of informal writing also provides a springboard for more formal derivative science writing (Keys, 1999).

Science Notebooks

The science notebook is an effective tool for enhancing learning in science and exercising various forms of writing. Notebooks provide opportunities both for expressive writing (students craft explanatory narratives that make sense of their science experiences) and for practicing informal technical writing (students use organizational structures and writing conventions). Students learn to communicate their thinking in an organized fashion while engaging in the cognitive processes required to develop concepts and build explanations. Having this developmental record of learning also provides an authentic means for assessing students’ progress in both scientific thinking and communication skills.

Developing Writing for Literacy in Science

Using student science notebooks in science instruction provides opportunities to address the CCSS for Writing in Science. Grades 6–8 students “write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.” In addition to providing a structure for recording and analyzing data, notebooks serve as a reference tool from which students can draw information in order to produce derivative products, that is, more formal science writing pieces that have a specific purpose and format. CCSS focus on three text types that students should be writing in science: argument, informational/explanatory writing, and narrative writing. These text types are used in science notebooks and can be developed into derivative products such as reports, articles, brochures, poster boards, electronic presentations, letters, and so forth. Following is a description of these three text types and examples that may be used with FOSS investigations to help students build scientific literacy.
Engaging in Argument

In science, middle school students make claims in the form of statements or conclusions that answer questions or address problems. CCSS Appendix A describes that for students to use “data in a scientifically acceptable form, students marshal evidence and draw on their understanding of scientific concepts to argue in support of their claims.” Applying the literacy skills necessary for this type of writing concurrently supports the development of critical science and engineering practices—most notably, engaging in argument. According to *A Framework for K–12 Science Education*, upon which the Next Generation Science Standards (NGSS) are based, middle school students are expected to construct a convincing argument that supports or refutes claims for explanations about the natural and designed world in these ways.

In FOSS, this type of writing makes students’ thinking visible. Both informally in their notebooks and formally on assessments, students use deductive and inductive reasoning to construct and defend their explanations. In this way, students deepen their science understanding and exercise the language functions necessary for higher-level thinking, for example, comparing, synthesizing, evaluating, and justifying. To support students in both oral and written argumentation, use the questions and prompts in the *Investigations Guide* that encourage students to use evidence, models, and theories to support their arguments. In addition, be prepared for those teachable moments that provide the perfect stage for spontaneous scientific debate. Here are some general questions to help students deepen their writing.

- Why do you agree or disagree with ______?  
- How would you prove/disprove ______?  
- What data did you use to make that conclusion that ______?  
- Why was it better that ______?

Here are the ways engaging in written argument are developed in the FOSS investigations and can be extended through formal writing.

**Response sheets.** The FOSS response sheets give students practice in constructing arguments by providing hypothetical situations where they have to apply what they have learned in order to evaluate a claim. For example, one of the response sheets in the *Planetary Science Course* asks students to respond to three students’ explanations for the seasons. Students write a paragraph to each student with the
purpose of changing his or her thinking. In order to refute each claim, students must evaluate the validity of the statements and construct arguments based on evidence from the data they’ve collected during the investigations and logical reasoning that supports their explanation for what causes seasons.

**Think questions.** Interactive reading in *FOSS Science Resources* is another opportunity for students to engage in written argumentation. Articles include questions that support reading comprehension and extend student thinking about the science content. Asking students to make a claim and provide evidence to support it encourages the use of language functions necessary for higher-level thinking such as evaluating, applying, and justifying. For example, in *FOSS Science Resources: Planetary Science*, students are asked to respond to the following question: Why do you think there are so few craters on Earth and so many on the Moon? After discussion with their peers, students can hone their argumentation skills by writing an argument that answers the question and is supported by the evidence in the *FOSS Science Resources* book as well as data recorded from their experience making model craters.

**I-Checks and surveys/posttests.** Like the FOSS response sheets, some test items assess students’ ability to make a claim and provide evidence to support it. One way is to provide students with data and have them make a claim based on that data and evidence from their prior investigations. Their argument should use logical reasoning to support their ideas. For example, in *Planetary Science*, students are shown images taken from two different planets. They are told that one has a thick atmosphere and the other has no atmosphere. They are asked which image they think came from a planet with an atmosphere and why. Using the images, they can see evidence of craters, and they can draw on their own experiences as well as knowledge acquired through other sources to piece together a logical argument.
**Persuasive writing.** Formal writing gives students the opportunity to summarize, explain, apply, and evaluate what they have learned in science. It also provides a purpose and audience that motivate students to produce higher-level writing products. The objective of persuasive writing is to convince the reader that a stated interpretation of data is worthwhile and meaningful. In addition to supporting claims with evidence and using logical argument, the writer also uses persuasive techniques such as a call to action. Students can use their informal notebook entries to form the basis of formal persuasive writing in a variety of formats, such as essays, letters, editorials, advertisements, award nominations, informational pamphlets, and petitions. Animal habitats, energy use, weather patterns, landforms, and water sources are just a few science topics that can generate questions and issues for persuasive writing.

Here is a sample of writing frames that can be used to introduce and scaffold persuasive writing (modified from Gibbons, 2002).

Title: ______

The topic of this discussion is ______.

My opinion (position, conclusion) is ______.

There are <number> reasons why I believe this to be true.

First, ______.

Second, ______.

Finally, ______.

On the other hand, some people think ______.

I have also heard people say ______.

However, my claim is that ______ because ______.
Informational/Explanatory Writing

Informational and explanatory writing requires students to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content. In middle school science, this includes writing scientific procedures and experiments. Described in CCSS Appendix A, informational/explanatory writing answers the questions, What type? What are the components? What are the properties, functions, and behaviors? How does it work? What is happening? Why? In FOSS, this type of writing takes place informally in science notebooks, where students are recording their questions, plans, procedures, data, and answers to the focus questions. It also supports sense making as students attempt to convey what they know in response to questions and prompts, using language functions such as identifying, comparing and contrasting, explaining cause-and-effect relationships, and sequencing.

As an extension of the notebook entries, students can apply their content knowledge to publish formal products such as letters, definitions, procedures, newspaper and magazine articles, posters, pamphlets, and research reports. Strategies such as the writing process (plan, draft, edit, revise, and share) and writing frames (modeling and guiding the use of topic sentences, transition and sequencing words, examples, explanations, and conclusions) can be used to scaffold and help students develop proficiency in science writing.

**Writing frames.** Here are samples of writing frames (modified from Wellington and Osborne, 2001).

**Description**

Title: _____

(Identify) The part of the _____ I am describing is the _____.

(Describe) It consists of _____.

(Explain) The function of these parts is _____.

(Example) This drawing shows _____.

**Explanation**

Title: _____

I want to explain why (how) _____.

An important reason for why (how) this happens is that _____.

Another reason is that _____.

I know this because _____.
Recursive cycle. An effective method for extending students’ science learning through writing is the recursive cycle of research (Bereiter, 2002). This strategy emphasizes writing as a process for learning, similar to the way students learn during the active science investigations.

1. Decide on a problem or question to write about.
2. Formulate an idea or a conjecture about the problem or question.
3. Identify a remedy or an answer, and develop a coherent discussion.
4. Gather information (from an experiment, science notebooks, FOSS Science Resources, FOSSweb multimedia, books, Internet, interviews, videos, etc.).
5. Reevaluate the problem or question based on what has been learned.
6. Revise the idea or conjecture.
7. Make presentations (reports, posters, electronic presentations, etc.).
8. Identify new needs, and make new plans.

This process can continue for as long as new ideas and questions occur, or students can present a final product in any of the suggested formats.

Narrative Writing
Narrative writing conveys an experience to the reader, usually with sensory detail and a sequence of events. In middle school science, students learn the importance of writing narrative descriptions of their procedures with enough detail and precision to allow others to replicate the experiment. Science also provides a broad landscape of stimulating material for stories, songs, biographies, autobiographies, poems, and plays. Students can enrich their science learning by using organisms or objects as characters; describing habitats and environments as settings; and writing scripts portraying various systems, such as weather patterns, states of matter, and the water, rock, or life cycle.

### CCSS NOTE
This example supports CCSS.ELA-Literacy.W.7.

### NOTE
Human characteristics should not be given to organisms (anthropomorphism) in science investigations, only in literacy extensions.

### CCSS NOTE
This example supports CCSS.ELA-Literacy.W.3.
**READING DOMAIN**

Reading is an integral part of science learning. Just as scientists spend a significant amount of their time reading each other’s published works, students need to learn to read scientific text—to read effectively for understanding, with a critical focus on the ideas being presented.

The articles in *FOSS Science Resources* facilitate sense making as students make connections to the science concepts introduced and explored during the active investigations. Concept development is most effective when students are allowed to experience organisms, objects, and phenomena firsthand before engaging the concepts in text. The text and illustrations help students make connections between what they have experienced concretely and the abstract ideas that explain their observations.

*FOSS Science Resources* provides students with clear and coherent explanations, ways of visualizing important information, and different perspectives to examine and question. As students apply these strategies, they are, in effect, using some of the same scientific thinking processes that promote critical thinking and problem solving. In addition, the text provides a level of complexity appropriate for middle schoolers to develop high-level reading comprehension skills. This development requires support and guidance as students grapple with more complex dimensions of language meaning, structure, and conventions. To become proficient readers of scientific and other academic texts, students must be armed with an array of reading comprehension strategies and have ample opportunities to practice and extend their learning by reading texts that offer new language, new knowledge, and new modes of thought.

Oral discourse and writing are critical for reading comprehension and for helping students make sense of the active investigations. Use the suggested prompts, questions, and strategies in the *Investigations Guide* to support comprehension as students read from *FOSS Science Resources*. For most of the investigation parts, the articles are designed to follow the active investigation and are interspersed throughout the course. This allows students to acquire the necessary background knowledge in context through active experience before tackling the wider-ranging content and relationships presented in the text. Breakpoints in the readings are suggested in the *Investigations Guide* to support student conceptual development. Some questions make connections between the reading and the student’s class experience. Other questions help the students consider the writer’s intent. Additional strategies for reading are derived from the seven essential strategies that readers use to help them understand what they read (Keene and Zimmermann, 2007).
• Monitor for meaning: discover when you know and when you don’t know.
• Use and create schemata: make connections between the novel and the known; activate and apply background knowledge.
• Ask questions: generate questions before, during, and after reading that reach for deeper engagement with the text.
• Determine importance: decide what matters most, what is worth remembering.
• Infer: combine background knowledge with information from the text to predict, conclude, make judgments, and interpret.
• Use sensory and emotional images: create mental images to deepen and stretch meaning.
• Synthesize: create an evolution of meaning by combining understanding with knowledge from other texts/sources.

**Reading Comprehension Strategies**

Below are some strategies that enhance the reading of expository texts in general and have proven to be particularly helpful in science. Read and analyze the articles beforehand in order to guide students through the text structures and content more effectively.

**Build on background knowledge.** Activating prior knowledge is critical for helping students make connections between what they already know and new information. Reading comprehension improves when students have the opportunity to think, discuss, and write about what they know about a topic before reading. Review what students learned from the active investigation, provide prompts for making connections, and ask questions to help students recall past experiences and previous exposure to concepts related to the reading.

**Create an anticipation guide.** Create true-or-false statements related to the key ideas in the reading selection. Ask students to indicate if they agree or disagree with each statement before reading, then have them read the text, looking for the information that supports their true-or-false claims. Anticipation guides connect students to prior knowledge, engage them with the topic, and encourage them to explore their own thinking. To provide a challenge for advanced students, have them come up with the statements for the class.

**Draw attention to vocabulary.** Check the article for bold faced words students may not know. Review the science words that are already defined in students’ notebooks. For new science and non-science...
vocabulary words that appear in the reading, have students predict their meanings before reading. During the reading, have students use strategies such as context clues and word structure to see if their predictions were correct. This strategy activates prior knowledge and engages students by encouraging analytical participation with the text.

**Preview the text.** Give students time to skim through the selection, noting subheads, before reading thoroughly. Point out the particular structure of the text and what discourse markers to look for. For example, most FOSS Science Resources articles are written as cause and effect, problem and solution, question and answer, comparison and contrast, description, or sequence. Students will have an easier time making sense of the text if they know what text structure to look for. Model and have students practice analyzing these different types of expository text structures by looking for examples, patterns, and discourse markers. For example, let’s look at a passage from FOSS Science Resources: Planetary Science.

An eclipse of the Moon occurs when Earth passes exactly between the Moon and the Sun. [cause and effect] The Moon moves into Earth’s shadow during a lunar eclipse. At the time of a full lunar eclipse, Earth’s shadow completely covers the disk of the Moon. [description] This is how Earth, the Moon, and the Sun are aligned for a lunar eclipse to be observed. [photograph] Why don’t we see a lunar eclipse every month? [question and answer] Because of the tilt of the Moon’s orbit around the Earth, Earth’s shadow does not fall on the Moon in most months.

Point out how the text in FOSS Science Resources is organized (titles, headings, subheadings, questions, and summaries) and if necessary, review how to use the table of contents, glossary, and index. Explain how to scan for formatting features that provide key information (such as boldface type and italics, captions, and framed text) and graphic features (such as tables, graphs, photographs, maps, diagrams, and charts) that help clarify, elaborate, and explain important information in the reading.

While students preview the article, have them focus on the questions that appear in the text, as well as questions at the end of the article. Encourage students to write down questions they have that they think the article will answer.

**Turn and talk.** When reading as a whole class, stop at key points and have students share their thinking about the selection with the student sitting next to them or with their collaborative group. This strategy helps students process the information and allows everyone to participate in the discussion. When reading in pairs, encourage
students to stop and discuss with their partners. One way to encourage engagement and understanding during paired reading is to have students take turns reading aloud a paragraph or section on a certain topic. The one who is listening then summarizes the meaning conveyed in the passage.

**Jigsaw text reading.** Students work together in small groups (expert teams) to develop a collective understanding of a text. Each expert team is responsible for one portion of the assigned text. The teams read and discuss their portions to gain a solid understanding of the key concepts. They might use graphic organizers to refine and organize the information. Each expert team then presents its piece to the rest of the class. Or form new jigsaw groups that consist of at least one representative from each expert team. Each student shares with the jigsaw group what their team learned from their particular portion of the text. Together, the participants in the jigsaw group fit their individual pieces together to create a complete picture of the content in the article.

**Note making.** The more students interact with a reading, the better their understanding. Encourage students to become active readers by asking them to make notes as they read. Studies have shown that note making—especially paraphrasing and summarizing—is one of the most effective means for understanding text (Graham and Herbert, 2010; Applebee, 1984). Some investigation parts include notebook sheets that match pages in *FOSS Science Resources*. This allows students to highlight and underline important points, add notes in the margins, and circle words they do not know. Students can also annotate the article by writing thoughts and questions on self-stick notes. Using symbols or codes can help facilitate comprehension monitoring. Here are some possible symbols students can use to communicate their thinking as they interact with text. (Harvey, 1998).

- * interesting
- BK background knowledge
- ? question
- C confusing
- I important
- L learning something new
- W wondering
- S surprising

*CCSS NOTE* This example supports CCSS.ELA-Literacy.RST.6–8.10.
Students can also use a different set of symbols while making notes about connections: the readings in FOSS Science Resources incorporate the active learning that students gain from the investigations, so that they can make authentic text-to-self (T-S) connections. In other words, what they read reminds them of firsthand experiences, making the article more engaging and easier to understand. Text-to-text (T-T) connections are notes students make when they discover a new idea that reminds them of something they’ve read previously in another text. Text-to-world (T-W) connections involve the text and more global everyday connections to students’ lives.

You can model note-making strategies by displaying a selection of text, using a projection system, a document camera, or an interactive whiteboard. As you read the text aloud, model how to write comments on self-stick notes, and use a graphic organizer in a notebook to enhance understanding.

**CCSS NOTE**
This example supports CCSS.ELA-Literacy.RST.6–8.1 and CCSS.ELA-Literacy.RST.6–8.2.

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**Transit Method**

If a planet passes directly in front of its star, the event is called a transit. During a transit, the planet blocks a small amount of the star’s light, causing a slight dimming of the star called a blink. The bigger the planet is, the bigger the drop in brightness, and the bigger the blink. From the largest planets, it’s not much of a blink. An observer from another planetary system would see a 1 percent drop in the star’s brightness when the large planet, Jupiter, passes in front of its star. That’s 1 part in 100. Earth would cause only a 0.01 percent drop in brightness, or 1 part in 10,000. The “blink” would actually be a long drop in brightness—2 to 16 hours—but short compared with the time it takes Earth to orbit its star.

Observing star blinks is the transit method of detecting exoplanets. As of September 2008, about 32 planets had been discovered by this method. Most were found by astronomers using ground-based observation, but four planets were discovered using a special brightness sensing satellite called CoRoT (Convection, Rotation, and planetary Transits). CoRoT was intended to probe the interior structure of stars by sensing tiny changes in star brightness, but it can also detect when a planet passes in front of its star. The Kepler Mission launched in March 2009. In February 2011, NASA released data of over 1,200 exoplanets candidates detected by the transit method using the Kepler space telescope.

For an up-to-date count of how many exoplanets have been discovered, visit www.FOSSweb.com.
Graphic organizers help students focus on extracting the important information from the reading and analyzing relationships between concepts. This can be done by simply having students make columns in their notebooks to record information and their thinking (Harvey and Goudvis, 2007). Here are two examples.

### Summarize and synthesize

Model how to pick out the important parts of the reading selection. Paraphrasing is one way to summarize. Have students write summaries of the reading, using their own words. To scaffold the learning, use graphic organizers to compare and contrast, group, sequence, and show cause and effect. Another method is to have students make two columns in their notebooks. In one column, they record what is important, and in the other, they record their personal responses (what the reading makes them think about). When writing summaries, tell students,

- **Pick out the important ideas.**
- **Restate the main ideas in your own words.**
- **Keep it brief.**

### 3-2-1

This graphic-organizer strategy gives students the opportunity to synthesize information and formulate questions they still have regarding the concepts covered in an article. In their notebooks, students write three new things they learned, two interesting things worth remembering and sharing, and one question that occurred to them while reading the article. Other options might include three facts, two interesting ideas, and one insight about themselves as learners; three key words, two new ideas, and one thing to think about (modified from Black Hills Special Services Cooperative, 2006).

### Write reflections

After reading, ask students to review their notes in their notebooks to make any additions, revisions, or corrections to what they recorded during the reading. This review can be facilitated by using a line of learning. Students draw a line under their original conclusion or under their answer to a question posed at the end of an article. They add any new information as a new narrative entry. The line of learning indicates that what follows represents a change of thinking.

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*Science-Centered Language Development in Middle School*
**Preview and predict.** Instruct students to independently preview the article, directing attention to the illustrations, photos, boldfaced words, captions, and anything else that draws their attention. Working with a partner, students discuss and write three things they think they will learn from the article. Have partners verbally share their list with another pair of students. The group of four can collaborate to generate one list. Groups report their ideas, and together you create a class list on chart paper.

Read the article aloud, or have students read with a partner aloud or silently. Referring to the preview/prediction list, discuss what students learned. Have them record the most important thing they learned from the reading for comparison with the predictions.

**SQ3R.** Survey, Question, Read, Recall, Reflect strategy provides an overall structure for before, during, and after reading. Students begin by surveying or previewing the text, looking for features that will help them make predictions about the content. Based on their surveys, students develop questions to answer as they read. They read the selections looking for answers to their questions. Next, they recall what they have learned by retelling a partner and/or recording what they’ve learned. Finally, they reflect on what they have learned, check to see that they’ve answered their questions sufficiently, and add any new ideas. Below is a chart students can use to record the SQ3R process in their notebooks.

<table>
<thead>
<tr>
<th>S Survey</th>
<th>Q Question</th>
<th>R Read</th>
<th>R Recall</th>
<th>R Reflect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan the text and record important information.</td>
<td>Ask questions about the subject and what you already know.</td>
<td>Record answers to your questions after you read.</td>
<td>Retell what you learned in your own words.</td>
<td>Did you answer your questions? Record new ideas and comments.</td>
</tr>
</tbody>
</table>
Struggling Readers
For students reading below grade level, the strategies listed on the previous pages can be modified to support reading comprehension by integrating scaffolding strategies such as read-alouds and guided reading. Breaking the reading down into smaller chunks, providing graphic organizers, and modeling reading comprehension strategies can also help students who may be struggling with the text. For additional strategies for English learners, see the supported-reading strategy in the English-Language Development section of this chapter.

Interactive reading aloud. Reading aloud is an effective strategy for enhancing text comprehension. It offers opportunities to model specific reading comprehension strategies and allows students to concentrate on making sense of the content. When modeling, share the thinking processes used to understand the reading (questioning, visualizing, comparing, inferring, summarizing, etc.), then have students share what they observed you thinking about as an active reader.

Guided reading. While the rest of the class is reading independently or in small groups, pull a group aside for a guided reading session. Before reading, review vocabulary words from the investigation and ask questions to activate prior knowledge. Have students preview the text to make predictions, ask questions, and think about text structure. Review reading comprehension strategies they will need to use (monitoring for understanding, asking questions, summarizing, synthesizing, etc.). As students read independently, provide support where needed. Ask questions and provide prompts to guide comprehension. (See the list below for additional strategies.) After reading, have students reflect on what strategies they used to help them understand the text and make connections to the investigation.

- While reading, look for answers to questions and confirm predictions.
- Study graphics, such as pictures, graphs, and tables.
- Reread captions associated with pictures, graphs, and tables.
- Note all italicized and boldfaced words or phrases.
- Reduce reading speed for difficult passages.
- Stop and reread parts that are not clear.
- Read only a section at a time, and summarize after each section.
SCIENCE-VOCABULARY DEVELOPMENT

Words play two critically important functions in science. First and most important, we play with ideas in our minds, using words. We present ourselves with propositions—possibilities, questions, potential relationships, implications for action, and so on. The process of sorting out these thoughts involves a lot of internal conversation, internal argument, weighing options, and complex linguistic decisions. Once our minds are made up, communicating that decision, conclusion, or explanation in writing or through verbal discourse requires the same command of the vocabulary. Words represent intelligence; acquiring the precise vocabulary and the associated meanings is key to successful scientific thinking and communication.

The words introduced in FOSS investigations represent or relate to fundamental science concepts and should be taught in the context of the investigation. Many of the terms are abstract and are critical to developing science content knowledge and scientific and engineering practices. The goal is for students to use science vocabulary in ways that demonstrate understanding of the concepts the words represent—not to merely recite scripted definitions. The most effective strategies for science-vocabulary development help students make connections to what they already know. These strategies focus on giving new words conceptual meaning through experience; distinguishing between informal, everyday language and academic language; and using the words in meaningful contexts.

Building Conceptual Meaning through Experience

In most instances, students should be presented with new words when they need to know them in the context of the active experience. Words such as kinetic energy, atmospheric pressure, chemical reaction, photosynthesis, and transpiration are abstract and conceptually loaded. Students will have a much better chance of understanding, assimilating, and remembering the new word (or new meaning) if they can connect it with a concrete experience.

The vocabulary icon appears in the sidebar when students are prompted to record new words in their notebook. The words that appear in bold are critical to understanding the concepts or scientific practices students are learning and applying in the investigation.
When you introduce a new word, students should

- Hear it: students listen as you model the correct contextual use and pronunciation of the word;
- See it: students see the new word written out;
- Say it: students use the new word when discussing their observations and inferences; and
- Write it: students use the new words in context when they write in their notebooks.

**Bridging Informal Language to Science Vocabulary**

FOSS investigations are designed to tap into students’ inquisitive nature and their excitement of discovery in order to encourage lively discussions as they explore materials in creative ways. There should be a lot of talking during the investigations! Your role is to help students connect informal language to the vocabulary used to express specific science concepts. As you circulate during active investigations, you continually model the use of science vocabulary. For example, as students are examining a leaf under the microscope, they will say, “I can see little mouths.” You might respond, “Yes, those mouthlike openings are called stomates. They are pores that open and close.” Below are some strategies for validating students’ conversational language while developing their familiarity with and appreciation for science vocabulary.

**Cognitive-content dictionaries.** Choose a term that is critical for conceptual understanding of the science investigation. Have students write the term, predict its meaning, write the final meaning after class discussion (using primary language or an illustration), and use the term in a sentence.

<table>
<thead>
<tr>
<th>Cognitive-Content Dictionary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New term</strong></td>
</tr>
<tr>
<td><strong>Prediction (clues)</strong></td>
</tr>
<tr>
<td><strong>Final meaning</strong></td>
</tr>
<tr>
<td><strong>How I would use it in a sentence</strong></td>
</tr>
</tbody>
</table>
Concept maps. Select six to ten related science words. Have students write them on self-stick notes or cards. Have small groups discuss how the words are related. Students organize words in groups and glue them down or copy them on a sheet of paper. Students draw lines between the related words. On the lines, they write words describing or explaining how the concept words are related.

Semantic webs. Select a vocabulary word, and write it in the center of a piece of paper (or on the board for the whole class). Brainstorm a list of words or ideas that are related to the first word. Group the words and concepts into several categories, and attach them to the central word with lines, forming a web (modified from Hamilton, 2002).

Word associations. In this brainstorming activity, you say a word, and students respond by writing the first word that comes to mind. Then students share their words with the class. This activity builds connections to students’ prior frames of reference.

Word sorts. Have students work with a partner to make a set of word cards using new words from the investigation. Have them group the words in different ways, for example, synonyms, root words, and conceptual connections.

Using Science Vocabulary in Context
For a new vocabulary word to become part of a student’s functional vocabulary, he or she must have ample opportunities to hear and use it. Vocabulary terms are used in the activities through teacher talk, whole-class and small-group discussions, writing in science notebooks, readings, and assessments. Other methods can also be used to reinforce important vocabulary words and phrases.

Word wall. Use chart paper to record science content and procedural words as they come up during and after the investigations. Students will use this word wall as a reference.

Drawings and diagrams. For English learners and visual learners, use a diagram to review and explain abstract content. Ahead of time, draw an illustration lightly, almost invisibly, with pencil on chart paper. You can do this easily by projecting the image onto the paper. When it’s time for the investigation, trace the illustration with markers as you introduce the words and phrases to students. Students will be amazed by your artistic ability.
**Cloze activity.** Structure sentences for students to complete, leaving out the vocabulary words. This can be done as a warm-up with the words from the previous day’s lesson. Here’s an example from the *Earth History Course*.

Teacher: *The removal and transportation of loose earth materials is called ______.*

Students: *Erosion.*

**Word wizard.** Tell students that you are going to lead a word activity. You will be thinking of a science vocabulary word. The goal is to figure out the word. Provide hints that have to do with parts of a definition, root word, prefix, suffix, and other relevant components. Students work in teams of two to four. Provide one hint, and give teams 1 minute to discuss. One team member writes the word on a piece of paper or on the whiteboard, using dark marking pens. Each team holds up its word for only you to see. After the third clue, reveal the word, and move on to the next word. Here’s an example.

1. *Part of the word means green.*
2. *They are found in plant cells.*
3. *They look like tiny green spheres or ovals.*

The word is *chloroplasts*.

**Word analysis/word parts.** Learning clusters of words that share a common origin can help students understand content-area texts and connect new words to familiar ones. Here’s an example: *geology, geologist, geological, geography, geometry, geophysical.* This type of contextualized teaching meets the immediate need of understanding an unknown word while building generative knowledge that supports students in figuring out difficult words for future reading.

**Breaking apart words.** Have teams of two to four students break a word into prefix, root word, and suffix. Give each team different words, and have each team share the parsed elements of the word with the whole class. Here’s an example.

*photosynthesis*

Prefix = *photo*: meaning light

Root = *synthesis*: meaning to put together
Possible sentences. Here is a simple strategy for teaching word meanings and generating class discussion.

1. Choose six to eight key concept words from the text of an article in FOSS Science Resources.
2. Choose four to six additional words that students are more likely to know something about.
3. Put the list of ten to fourteen words on the board or project it. Provide brief definitions as needed.
4. Ask students to devise sentences that include two or more words from the list.
5. On chart paper, write all sentences that students generate, both coherent and otherwise.
6. Have students read the article from which the words were extracted.
7. Revisit students’ sentences, and discuss whether the sentences are sensible based on the passage or how they could be modified to be more coherent.

Reading. After the active investigation, students continue to develop their understanding of the vocabulary words and the concepts those words represent by listening to you read aloud, reading with a partner, or reading independently. Use strategies discussed in the Reading Domain section to encourage students to articulate their thoughts and practice the new vocabulary.

Glossary. Emphasize the vocabulary words students should be using when they answer the focus question in their science notebooks. The glossary in FOSS Science Resources or on FOSSweb can be used as a reference.

Index. Have students create an index at the back of their notebooks. There they can record new vocabulary words and the notebook page where they defined and used the new words for the first time in the context of the investigation.

Poems, chants, and songs. As extensions or homework assignments, ask students to create poems, raps, chants, or songs, using vocabulary words from the investigation.
ENGLISH-LANGUAGE DEVELOPMENT

Active investigations, together with ample opportunities to develop and use language, provide an optimal learning environment for English learners. This section highlights opportunities for English-language development (ELD) in FOSS investigations and suggests other best practices for facilitating both the learning of new science concepts and the development of academic literacy. For example, the hands-on structure of FOSS investigations is essential for the conceptual development of science content knowledge and the habits of mind that guide and define scientific and engineering practices. Students are engaged in concrete experiences that are meaningful and that provide a shared context for developing understanding—critical components for language acquisition.

When getting ready for an investigation, review the steps and determine the points where English learners may require scaffolds and where the whole class might benefit from additional language-development supports. One way to plan for ELD integration in science is to keep in mind four key areas: prior knowledge, comprehensible input, academic language development, and oral practice. The ELD chart lists examples of universal strategies for each of these components that work particularly well in teaching science.

<table>
<thead>
<tr>
<th>English-Language Development (ELD)</th>
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<tbody>
<tr>
<td>Activating prior knowledge</td>
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<tr>
<td>• Inquiry chart</td>
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<tr>
<td>• Circle map</td>
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<tr>
<td>• Observation poster</td>
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<tr>
<td>• Quick write</td>
</tr>
<tr>
<td>• Kit inventory</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Developing academic language</td>
</tr>
<tr>
<td>• Language objectives</td>
</tr>
<tr>
<td>• Sentence frames</td>
</tr>
<tr>
<td>• Word wall, word cards, drawings</td>
</tr>
<tr>
<td>• Concept maps</td>
</tr>
<tr>
<td>• Cognitive content dictionaries</td>
</tr>
</tbody>
</table>
Students acquiring English benefit from scaffolds that support the language forms and functions necessary for the academic demands of the science course, that is, accessing science text, participating in productive oral discourse, and engaging in science writing. The table at the end of this section (starting on page 38) provides a resource to help students organize their thinking and structure their speaking and writing in the context of the science and engineering practices. The table identifies key language functions exercised during FOSS investigations and provides examples of sentence frames students can use as scaffolds.

For example, if students are planning an investigation to learn more about insect structures and behaviors, the language objective might be “Students plan and design an investigation that answers a question about the hissing cockroach’s behavior.” For students who need support, a sentence frame that prompts them to identify the variables in the investigation would provide language forms and structures appropriate for planning their investigation. As a scaffold, sentence frames can also help them write detailed narratives of their procedure. Here’s an example from the table.

<table>
<thead>
<tr>
<th>Language functions</th>
<th>Language objectives</th>
<th>Sentence frames</th>
</tr>
</thead>
</table>
| Planning and carrying out investigations | Plan controlled experiments with multiple trials. Identify independent variable and dependent variable. Discuss, describe, and evaluate the methods for collecting data. | To find out _______, I will change _______. I will not change _______. I will measure _______. I will observe _______. I will record the data by _______. First, I will _______, and then I will _______. To learn more about _______, I will need _______ to _______.

**NOTE**

Language forms and structures are the internal grammatical structure of words and how those words go together to make sentences.

**NOTE**
The complete table appears at the end of the English-Language Development section starting on page 38.
**Activating Prior Knowledge**

When an investigation engages a new concept, students first recall and discuss familiar situations, objects, or experiences that relate to and establish a foundation for building new knowledge and conceptual understanding. Eliciting prior knowledge also supports learning by motivating interest, acknowledging culture and values, and checking for misconceptions and prerequisite knowledge. This is usually done in the first steps of Guiding the Investigation in the form of a discussion, presentation of new materials, or a written response to a prompt. The tools outlined below can also be used before beginning an investigation to establish a familiar context for launching into new material.

**Circle maps.** Draw two concentric circles on chart paper. In the smaller circle, write the topic to be explored. In the larger circle, record what students already know about the subject. Ask students to think about how they know or learned what they already know about the topic. Record the responses outside the circles. Students can also do this independently in their science notebooks.

An example of a circle map

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**Activating Prior Knowledge**

- **Circle maps**
- **Observation posters**
- **Quick writes**
- **Kit inventories**
Observation posters. Make observation posters by gluing or taping pictures and artifacts relevant to the module or a particular investigation onto pieces of blank chart paper or poster paper. Hang them on the wall in the classroom, and have students rotate in small groups to each poster. At each poster, students discuss their observations with their partners or small groups and then record (write or draw) an observation, a question, a prediction, or an inference about the pictures as a contribution to the commentary on the poster.

As a variation on this strategy, give a set of pictures to each group to pass around. Have them choose one and write what they notice, what they infer, and questions they have in their notebooks.

Quick writes. Ask students what they know about the topic of the investigation. Responses can be recorded independently as a quick write in notebooks and then shared collaboratively. Do not correct misconceptions initially. Periodically revisit the quick-write ideas as a whole class, or have students review their notebook entries to correct, confirm, or complete their original thoughts as they acquire new information (possibly using a line of learning). At the conclusion of the investigation, students should be able to express mastery of the new conceptual material.

Kit inventories. Introduce each item from the FOSS kit used in the investigation, and ask students questions to get them thinking about what each item is and where they may have seen it before. Have them describe the objects and predict how they will be used in the investigation.
Comprehending Input
To initiate their own sense making, students must be able to access the information presented to them. We refer to this ability as comprehending input. Students must understand the essence of new ideas and concepts before beginning to construct new scientific meaning. The strategies for comprehensible input used in FOSS ensure that the instruction is understandable while providing students with the opportunity to grapple with new ideas and the critically important relationships between concepts. Additional tools such as repetition, visual aids, emphasis on procedural vocabulary, and auditory reinforcement can also be used to enhance comprehensible input for English learners.

**Content objectives.** The focus question for each investigation part frames the activity objectives—what students should know or be able to do at the end of the part. Making the learning objectives clear and explicit prepares English learners to process the delivery of new information, and helps you maintain the focus of the investigation. Write the focus question on the board, have students read it aloud and transcribe it into their science notebooks, and have students answer the focus question at the end of the investigation part. You then check their responses for understanding.

**Multiple exposures.** Repeat an activity in an analogous but slightly different context, ideally one that incorporates elements that are culturally relevant to students. For example, as a homework assignment for landforms, have students interview their parents about landforms common in the area of their ancestry.

**Visual aids.** On the board or chart paper, write out the steps for conducting the investigation. This provides a visual reference. Include illustrations if necessary. Use graphic representations (illustrations drawn and labeled in front of students) to review the concepts explored in the active investigations. In addition to the concrete objects in the kit, use realia to augment the activity, to help English learners build understanding and make cultural connections. Graphic organizers (webs, Venn diagrams, T-tables, flowcharts, etc.) aid comprehension by helping students see how concepts are related.

**Supported reading.** In addition to the reading comprehension strategies suggested in the Reading Domain section of this chapter, English learners can also benefit from methods such as front-loading key words, phrases, and complex text structures before reading; using
Science-Centered Language Development in Middle School

**Procedural Vocabulary**
Add
Analyze
Assemble
Attach
Calculate
Change
Classify
Collect
Communicate
Compare
Connect
Construct
Contrast
Demonstrate
Describe
Determine
Draw
Evaluate
Examine
Explain
Explore
Fill
Graph
Identify
Illustrate
Immerse
Investigate
Label
List
Measure
Mix
Observe
Open
Order
Organize
Pour
Predict
Prepare
Record
Represent
Scratch
Separate
Sort
Stir
Subtract
Summarize
Test
Weigh

preview-review (main ideas are previewed in the primary language, read in English, and reviewed in the primary language); and having students use sentence frames specifically tailored to record key information and/or graphic organizers that make the content and the relationship between concepts visually explicit from the text as they read.

**Procedural vocabulary.** Make sure students understand the meaning of the words used in the directions for an investigation. These may or may not be science-specific words. Use techniques such as modeling, demonstrating, and body language (gestures) to explain procedural meaning in the context of the investigation. The words students will encounter in FOSS include those listed in the sidebar. To build academic literacy, English learners need to learn the multiple meanings of these words and their specific meanings in the context of science.

**Developing Academic Language**
As students learn the nuances of the English language, it is critical that they build proficiency in academic language in order to participate fully in the cognitive demands of school. *Academic language* refers to the more abstract, complex, and specific aspects of language, such as the words, grammatical structure, and discourse markers that are needed for higher cognitive learning. FOSS investigations introduce and provide opportunities for students to practice using the academic vocabulary needed to access and engage with science ideas.

**Language objectives.** Consider the language needs of English learners and incorporate specific language-development objectives that will support learning the science content of the investigation, such as a specific way to expand use of vocabulary by looking at root words, prefixes, and suffixes; a linguistic pattern or structure for oral discussion and writing; or a reading comprehension strategy. Recording in science notebooks is a productive way to optimize science learning and language objectives. For example, in the *Earth History Course*, one language objective might be “Students will apply techniques for rock observations to compare and contrast sedimentary and igneous rocks. They will discuss and record their observations in their notebooks in an organized manner.”
**Vocabulary development.** The Science-Vocabulary Development section in this chapter describes the ways science vocabulary is introduced and developed in the context of an active investigation and suggests methods and strategies that can be used to support vocabulary development during science instruction. In addition to science vocabulary, students need to learn the nonscience vocabulary that facilitates deeper understanding and communication skills. Words such as *release, convert, beneficial, produce, receive, source,* and *reflect* are used in the investigations and *FOSS Science Resources* and are frequently used in other content areas. Learning these academic-vocabulary words gives students a more precise and complex way of practicing and communicating productive thinking. Consider using the strategies described in the Science-Vocabulary Development section to explicitly teach targeted, high-leverage words that can be used in multiple ways and that can help students make connections to other words and concepts. Sentence frames, word walls, concept maps, and cognitive-content dictionaries are strategies that have been found to be effective with academic-vocabulary development.
## Scaffolds That Support Science and Engineering Practices

<table>
<thead>
<tr>
<th>Language functions</th>
<th>Language objectives</th>
<th>Sentence frames</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Asking questions and defining problems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inquire</td>
<td>Ask questions to solicit information about phenomena, models, or unexpected results; determine the constraints and criteria of a problem.</td>
<td>I wonder why ____ .</td>
</tr>
<tr>
<td>Define a problem</td>
<td></td>
<td>What happens when ____ ?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What if ____ ?</td>
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<td></td>
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<td>What does ____ ?</td>
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<td>What can ____ ?</td>
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<td></td>
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<td>What would happen if ____ ?</td>
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<td></td>
<td></td>
<td>How does ____ affect ____ ?</td>
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<td></td>
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<td>How can I find out if ____ ?</td>
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<td></td>
<td></td>
<td>Which ____ is better for ____ ?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Planning and carrying out investigations</strong></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>Plan controlled experiments with multiple trials. Identify independent variable and dependent variable.</td>
<td>To find out ____ , I will change ____ .</td>
</tr>
<tr>
<td>Sequence</td>
<td>Discuss, describe, and evaluate the methods for collecting data.</td>
<td>I will not change ____ .</td>
</tr>
<tr>
<td>Strategize</td>
<td></td>
<td>I will measure ____ .</td>
</tr>
<tr>
<td>Evaluate</td>
<td></td>
<td>I will observe ____ .</td>
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<td></td>
<td>I will record the data by ____ .</td>
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<td>First, I will ____ , and then I will ____ .</td>
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<td></td>
<td></td>
<td>To learn more about ____ , I will need ____ to ____ .</td>
</tr>
<tr>
<td>Language functions</td>
<td>Language objectives</td>
<td>Sentence frames</td>
</tr>
<tr>
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</tr>
<tr>
<td><strong>Planning and carrying out investigations (continued)</strong></td>
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</tbody>
</table>
| Describe | Write narratives using details to record sensory observations and connections to prior knowledge. | I observed/noticed ____.
When I touch the ____ I feel ____.
It smells ____.
It sounds ____.
It reminds me of ____, because ____.
|
| Organize | Make charts and tables: use a T-table or chart for recording and displaying data. | The table compares ____ and ____.
|
| Compare Classify | | |
| Sequence | Record changes over time, and describe cause-and-effect relationships. | At first, ____ but now ____.
We saw that first ____ then ____ and finally ____.
When I ____ it ____.
After I ____ it ____.
|
| Compare | | |
| Draw | Draw accurate and detailed representations; identify and label parts of a system using science vocabulary, with attention to form, location, color, size, and scale. | The diagram shows ____ is shown here.
____ is ____ times bigger than ____.
____ is ____ times smaller than ____.
|
| Label Identify | | |
| **Analyzing and interpreting data** | | |
| Enumerate | Use measures of variability to analyze and characterize data; decide when and how to use bar graphs, line plots, and two-coordinate graphs to organize data. | The mean is ____.
The median is ____.
The mode is ____.
The range is ____.
The x-axis represents ____ and the y-axis represents ____.
The units are expressed in ____.
### Analyzing and interpreting data (continued)

<table>
<thead>
<tr>
<th>Language functions</th>
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</tr>
</thead>
</table>
| Compare Classify Sequence | Use graphic organizers and narratives to express similarities and differences, to assign an object or action to the category or type to which it belongs, and to show sequencing and order. | This ____ is similar to ____ because ____  
This ____ is different from ____ because ____  
All these are ____ because ____  
____, ____ , and ____ all have/are ____ |
| Analyze | Use graphic organizers, narratives, or concept maps to identify part/whole or cause–and–effect relationships. Express data in qualitative terms such as more/fewer, higher/lower, nearer/farther, longer/shorter, and increase/decrease; and quantitatively in actual numbers or percentages. | The ____ consists of ____  
The ____ contains ____  
As ____ , then ____  
When I changed ____ , then ____ happened.  
The more/less ____ , then ____ |

### Developing and using models

<table>
<thead>
<tr>
<th>Language functions</th>
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</table>
| Represent Predict Explain | Construct and revise models to predict, represent, and explain. | If ____ , then ____ , therefore ____  
The ____ represents ____  
____ shows how ____  
You can explain ____ by ____ |
<table>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Using mathematics and computational thinking</strong></td>
<td></td>
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</tbody>
</table>
| Symbolize Measure Enumerate Estimate | Use mathematical concepts to analyze data. | The ratio of _____ is _____ to _____.
| | | The average is _____.
| | | Looking at _____, I think there are _____.
| | | My prediction is _____.
| **Constructing explanations and designing solutions** | | |
| Infer Explain | Construct explanations based on evidence from investigations, knowledge, and models; use reasoning to show why the data are adequate for the explanation or conclusion. | I claim that ____. I know this because _____.
| | | Based on ____, I think ____. As a result of ____, I think _____.
| | | The data show ____, therefore, ____.
| | | I think ____ means ____ because ____.
| | | I think ____ happened because ____.
| Provide evidence | Use qualitative and quantitative data from the investigation as evidence to support claims. | My data show ____.
| | | My evidence is ____.
| | | Use quantitative expressions using standard metric units of measurement such as cm, mL, °C.
| | | The relationship between the variables is ____.
| | | The model of ____ shows that ____.
<table>
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</thead>
<tbody>
<tr>
<td><strong>Discuss</strong></td>
<td>Use oral and written arguments supported by evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem.</td>
<td>I think ___ because___.</td>
</tr>
<tr>
<td><strong>Persuade</strong></td>
<td></td>
<td>I agree/disagree with ___ because________.</td>
</tr>
<tr>
<td><strong>Synthesize</strong></td>
<td></td>
<td>What you are saying is ______. What do you think about _____?</td>
</tr>
<tr>
<td><strong>Negotiate</strong></td>
<td></td>
<td>What if _____?</td>
</tr>
<tr>
<td><strong>Suggest</strong></td>
<td></td>
<td>I think you should try ___.</td>
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<tr>
<td></td>
<td></td>
<td>Another way to interpret the data is ______.</td>
</tr>
<tr>
<td><strong>Critique</strong></td>
<td>Evaluate competing design solutions based on criteria; compare two arguments from evidence to identify which is better.</td>
<td>____ makes more sense because ____.</td>
</tr>
<tr>
<td><strong>Evaluate</strong></td>
<td></td>
<td>____ is a better design ____ because it ____.</td>
</tr>
<tr>
<td><strong>Reflect</strong></td>
<td></td>
<td>Comparing ___ to ___ shows that ______.</td>
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<td>One discrepancy is ____.</td>
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<tr>
<td></td>
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<td>____ is inconsistent with ____.</td>
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<td></td>
<td>Another way to determine ______ is to ______.</td>
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<td></td>
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<td>I used to think ___ but now I think _____. I have changed my thinking about ____.</td>
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<td>I am confused about ____ because ____.</td>
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<td>I wonder ____.</td>
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</tbody>
</table>

**Obtaining, evaluating, and communicating information**

(These practices include all functions described in the other practices above.)
REFERENCES


