chapter 1

The Academic Language of Science

In most states, English learners (ELs) are struggling to meet academic targets in science set by the No Child Left Behind Act. One factor contributing to the difficulty ELs experience is that science is more than just doing experiments and observing natural phenomena; science education involves technical terms and associated concepts, oral or written instructions on how to conduct laboratory experiments, classroom academic language used in a teacher's explanation of a process, textbook reading, and report writing. Language plays a large and important role in learning science.

Consider the following situation. Your sister called earlier with some horrible news. Your three-year-old nephew has been diagnosed with Wilms' tumor. You have never heard of it and even your sister's explanation that it is a type of child's kidney disease, a cancer, doesn't ring any bells. Knowing you teach science, she is asking for your help in understanding the disease and the possible treatments.

You immediately begin with Internet searches. *Wikipedia* (Retrieved June 26, 2009 from http://en.wikipedia.org/wiki/Wilms'_tumor) gives you the following:

> Wilms' tumor or nephroblastoma is a tumor of the kidneys that typically occurs in children, rarely in adults. Pathologically, a triphasic nephroblastoma comprises three elements:
>
> blastema
>
> mesenchyme
>
> epithelium
>
> Wilms' tumor is a malignant tumor containing metanephric blastema, stromal and epithelial derivatives. Characteristic is the presence of abortive tubules and glomeruli surrounded by a spindled cell stroma. The stroma may include striated muscle, cartilage, bone, fat tissue, fibrous tissue. The tumor is compressing the normal kidney parenchyma.
>
> The mesenchymal component may include cells showing rhabdomyoid differentiation. The rhabdomyoid component may itself show features of malignancy (*rhabdomyosarcomatous Wilms*).

This doesn't help you understand the disease very much. You don't know many of the technical terms—*blastema, mesenchyme, metanephric, stromal, glomeruli*, and *rhabdomyoid*—although you do recognize that some sentences are formulated like definitions: *Wilms' tumor IS a malignant tumor containing. . . , The stroma MAY INCLUDE. . . .* It makes you remember a workshop you attended a few weeks ago in which the facilitator said that research reveals that we can only read independently if we know 90%–95% of the words.[1] In reading "The mesenchymal component may include cells showing rhabdomyoid differentiation," you know seven of the nine words, or 78%, but not the key ones that would convey meaning. What's *mesenchymal*? What's *rhabdomyoid*? This isn't going to help your sister and nephew determine a course of action without additional support.

So you read on and find some good news, "It is highly responsive to treatment, with about 90% of patients surviving at least five years." You continue reading eagerly, but the prognosis section doesn't help you understand what to do or how to help your nephew:

> Tumor-specific loss-of-heterozygosity (LOH) for chromosomes 1p and 16q identifies a subset of Wilms tumor patients who have a significantly increased risk of relapse and death. LOH for these chromosomal regions can now be used as an independent prognostic factor together with disease stage to target intensity of treatment to risk of treatment failure.[3][4] Genome-wide copy number and LOH status can be assessed with virtual karyotyping of tumor cells (fresh or paraffin-embedded).

This is frustrating. You are accustomed to reading science texts. You can figure out general academic words like *identifies, subset, increased, risk, regions,* and others, but you can't determine whether this paragraph is useful in your nephew's circumstances. Does he have an increased risk of relapse and death? What is loss-of-heterozygosity? If something is favorable, why would the text indicate it leads to increased risk of death?

Despite being well read and well educated, we have all had experiences where we became lost when listening to or reading about a new and unfamiliar topic. We're tripped

[1]Nagy & Scott, 2000.

up by the terminology, phrases, and concepts that are unique to the subject matter. When this happens, we most likely become frustrated and sometimes lose interest. But in this particular case, you don't want to give up because you want to help your nephew. Further, with your university education, you know how to access additional resources and how to reach out to knowledgeable experts for the information you and your sister will need.

However, every day, many English learners sit in classrooms where the topic, the related words, and concepts are totally unfamiliar to them. Other English learners may have familiarity with the topic, perhaps even some expertise, but because they don't know the English words, terminology, and phrases—that is, the content-specific academic language—they are also unable to understand what is being taught. Comprehension can be compromised as well when they don't understand cause-effect sentence structures or the usage of such prepositions and conjunctions as except, *unless*, *but*, *despite*, or *however*. Moreover, they have not yet mastered how to use language and content resources to help them understand.

What Is Academic Language?

Although definitions in the research literature differ somewhat, there is general agreement that academic language is both general- and content-specific. That is, many academic words are used across all content areas (such as *demonstrate, conflict, analyze, element, category*), whereas others pertain to specific subject areas (*photosynthesis, mitosis, density, hypothesize,* and *inertia* for science; *angle, ratio, dispersion,* and *calculate* for math). It is important to remember that academic language is more than specific content vocabulary words related to particular topics. Rather, academic language represents the entire range of language used in academic settings, including elementary and secondary schools. Consider the following definitions offered by several educational researchers:

- Academic language is "the language that is used by teachers and students for the purpose of acquiring new knowledge and skills . . . imparting new information, describing abstract ideas, and developing students' conceptual understandings" (Chamot & O'Malley, 1994, p. 40).
- Academic language refers to "word knowledge that makes it possible for students to engage with, produce, and talk about texts that are valued in school" (Flynt & Brozo, 2008, p. 500).
- "Academic English is the language of the classroom, of academic disciplines (science, history, literary analysis) of texts and literature, and of extended, reasoned discourse. It is more abstract and decontextualized than conversational English" (Gersten, Baker, Shanahan, Linan-Thompson, Collins, & Scarcella, 2007, p. 16).
- Academic English "refers to more abstract, complex, and challenging language that will eventually permit you to participate successfully in mainstream classroom instruction. Academic English involves such things as relating an event or a series of events to someone who was not present, being able to make comparisons between alternatives and justify a choice, knowing different forms, and inflections of words and their appropriate use, and possessing and using content-specific vocabulary and modes of expression in different academic disciplines such as mathematics and social studies" (Goldenberg, 2008, p. 9).

- "Academic language is the set of words, grammar, and organizational strategies used to describe complex ideas, higher-order thinking processes, and abstract concepts" (Zwiers, 2008, p. 20).

When you reflect on the examples for science and mathematics, you can see that academic language differs considerably from the social, conversational language that is used on the playground, at home, or at cocktail parties. Social or conversational language is generally more concrete than abstract, and it is usually supported by contextual clues, such as gestures, facial expressions, and body language (Cummins, 1979, 2000; Echevarria & Graves, 2007).

Some educators suggest that the distinction between conversational and academic language is somewhat arbitrary and that it is the *situation, community,* or *context* that is either predominantly social or academic (Aukerman, 2007; Bailey, 2007). For purposes of this book, we maintain that academic language is essential for success in school and that it is more challenging to learn than conversational English, especially for students who are acquiring English as a new language. Although knowing conversational language assists students in learning academic language, we must explicitly teach English learners (and other students, including native speakers) the "vocabulary, more complex sentence structures, and rhetorical forms not typically encountered in nonacademic settings" (Goldenberg, 2008, p. 13).

A focus on words, grammar, and oral and written discourse as applied in school settings is likely to increase student performance levels. Analyses of language used in assessments by Bailey and Butler (2007) found two types of academic language: content-specific language (e.g., technical terms such as *latitude* and *longitude*, and phrases such as "We hypothesize that . . .") and general, or common core, academic language (e.g., persuasive terms, comparative phrases) that is useful across curricular areas. Similarly, there are general academic tasks that one needs to know how to do in order to be academically proficient (e.g., create an outline, take notes) and more specific tasks (e.g., write a scientific laboratory report). They argue that teachers and curricula should pay attention to this full range of academic language and that the enhancement of ELs' academic language skills should enable them to perform better on assessments. This conclusion is bolstered by Snow, et al. (1991), who found that performance on highly decontextualized (i.e., school-like) tasks, such as providing a formal definition of words, predicted academic performance, whereas performance on highly contextualized tasks, such as face-to-face communication, did not.

How Is Academic Language Manifested in Classroom Discourse?

Our teachers come to class,
And they talk and they talk,
Til their faces are like peaches,
We don't;
We just sit like cornstalks.

(Cazden, 1976, p. 74)

These poignant words come from a Navajo child who describes a classroom as she sees it. Teachers like to talk. Just observe any classroom and you'll find that the teacher does the vast majority of the speaking. That might be expected because the teacher, after all, is the most expert science person in the classroom. However, for students to develop proficiency in language, interpret what they read and view, express themselves orally and in writing, participate during whole-group instruction and small-group interaction, and explain and defend their answers, they need opportunities to learn and use academic language.

Many of the visible manifestations of academic language use in the classroom come from the conversations between teacher and students, and on occasion among students. Most instructional patterns involve the teacher initiating a topic (I) usually by asking a question, a student responding (R), the teacher evaluating (E) the response or providing feedback (F), followed by another teacher-asked question (Cazden, 1986; 2001; Mehan, 1979; Watson & Young, 1986). A typical interaction between a teacher and her students during a science lesson is illustrated in the following example:

T: Who can name one of the three types of rocks we studied yesterday?

S: Igneous.

T: Right. Igneous rock comes from volcanoes. Who can tell us another type?

S: Sed-, sedi-, sedimentary.

T: That's right. Good. This rock type is a result of little bits of rocks and sand pressing together in layers over time.

And on it goes, often for a good portion of the lesson. Notice that the teacher asked questions that had a correct answer with no reasoning or higher level thinking required; in fact, the verb "name" in the teacher's question indicates she is asking for a factual recall. The teacher controlled the interchange, and the teacher evaluated student responses. Also note that the only person in the interchange to actually orally produce elaborated academic language (in this case, definitions of the types of rocks) was the teacher. The students didn't need to use more than one or two words in response to the teacher's questions in order to participate appropriately. But it is the students who need to practice using academic language, not the teacher! Further, only two students were involved; the others were quiet.

The Initiation-Response-Evaluation/Feedback (IRE/F) pattern is quite typical and it has been found to be one of the least effective interactional patterns for the classroom (Cazden, 1986; 2001; Mehan, 1979; Watson & Young, 1986). More similar to an interrogation than to a discussion, this type of teacher–student interaction stifles academic language development and does not encourage higher level thinking because most of the questions have a straightforward, known answer. Further, we have observed from kindergarten through high school that most students become conditioned to wait for someone else to answer. Often it is the teacher who ultimately answers his or her own question, if no students volunteer. Or the teacher elaborates, as in the third and fifth lines above.

In classrooms where the IRE/F pattern dominates, the teacher's feedback may inhibit learning when he or she changes students' responses by adding to or deleting from their statements or by completely changing a student's intent and meaning. Because the teacher is searching for a preconceived answer and often "fishes" until it is found, the cognitive work of the lesson is often carried out by the teacher rather than the students. In these

classrooms, students are seldom given the opportunity to elaborate on their answers; rather, the teacher does the analyzing, synthesizing, generalizing, and evaluating.

Changing ineffective classroom discourse patterns by creating authentic opportunities for students to develop academic language is critically important because as one acquires language, new concepts are also developed. Think about the experience described previously regarding websites with information about Wilms' tumor. Each new vocabulary word you learned and understood (e.g., metanephric blastema, loss-of-heterozygosity) is attached to a concept that in turn expands your ability to think about and begin to understand your nephew's disease and consider courses of action. As your own system of word-meaning grows in complexity, you are more capable of understanding the associated concepts and generating the self-directed speech of verbal thinking, such as "If we can determine my nephew's loss of heterozygosity for certain chromosome areas, we'll have a sense of whether the treatment might work in the long run." Without an understanding of the words and the concepts they represent, you would be incapable of thinking about (self-directed speech) or discussing (talking with another) Wilms' tumor disease.

Academic English also involves reading and writing. As you most likely know, the National Reading Panel (National Institute of Child Health and Human Development, 2000) defined the major components of reading as phonics, phonemic awareness, fluency, vocabulary, and reading comprehension. Research suggests that high-quality instruction in these five components generally works for English learners as well, although additional focus on oral language development and background building are called for to enhance comprehension (August & Shanahan, 2006; Goldenberg, 2008).

Although English learners are able to attain well-taught word-level skills such as decoding, word recognition, and spelling that are equal to their English-speaking peers, the same is not typically the case with text-level skills such as reading comprehension and writing (Goldenberg, 2008). One reason for the disparity between word-level and text-level skills among English learners is oral English proficiency. Well-developed oral proficiency in English, which includes English vocabulary and syntactic knowledge plus listening comprehension skills, is associated with English reading and writing proficiency. Therefore, it is insufficient to teach English learners the components of reading alone; teachers also must incorporate extensive oral language development opportunities into literacy instruction. Further, English learners benefit from more opportunities to practice reading, check comprehension, and consolidate text knowledge through summarization. They also need instruction on the features of different text genres, especially those found in subject area classes—such as textbook chapters, online articles, laboratory directions, diagrams and other graphics, and primary source materials. Since reading is the foundation for learning in school, it is critical that teachers use research-based practices to provide English learners with high-quality instruction that will lead to the development of strong reading skills.

Academic writing is an area that is affected significantly by limited English proficiency. While oral skills can be developed as students engage in meaningful activities, skills in writing must be explicitly taught. The writing process, which involves planning, drafting, editing, and revising written work, allows students to express their ideas at their level of proficiency with teacher (or peer) guidance and explicit corrective feedback. However, for English learners, it is critical that a lot of meaningful discussion take place prior to asking students to write because such dialogue helps connect ideas in support of writing and provides students with the English words they will use. Writing is also

facilitated by such things as teacher modeling, posting of writing samples, providing sentence frames, and even having students copy words or text until they gain more independent proficiency (Graham & Perin, 2007). This kind of constant exposure to words and sentence patterning allows ELs to become familiar with the conventions of how words and sentences are put together in the language (Garcia & Beltran, 2003).

English learners should be encouraged to write in English early, especially if they have skills in their native language, and should be provided frequent opportunities to express their ideas in writing. Errors in writing are to be expected and should be viewed as part of the natural process of language acquisition. Providing scaffolded writing tools, such as partially completed graphic organizers for pre-writing and sentence frames for organizing key points and supporting details will help ELs write in the content classroom.

What Is the Academic Language of Science?

A focus on teaching the language of science is not new, but it is still not widespread in practice, although *Science for English Language Learners* (Fathman & Crowther, 2006), *Teaching Science to English Language Learners* (Rosebery & Warren, 2008), and *Making Science Accessible for English Learners* (Carr, Sexton, & Lagunoff, 2007) are recent, useful resources. In the 1980s, Lemke began examining science discourse and its implications for students learning English as a new language. At that time, he explained,

> [E]ducators have begun to realize that the mastery of academic subjects is the mastery of their specialized patterns of language use, and that language is the dominant medium through which these subjects are taught and students' mastery of them tested. (Lemke, 1988, p. 81)

Lemke (1990) pointed out that "scientific language has a preference in its grammar for using the passive voice . . . people tend to disappear from science as actors or agents . . . [and there is] a grammatical preference for using abstract nouns derived from verbs" (p. 130). He criticized these stylistic conventions because they made science less accessible and less engaging to students. "(T)eachers tend to leave much of the semantics and grammar of scientific language completely implicit" (Lemke, 1990, p. 170). Criticism like Lemke's is one of the reasons we developed the SIOP® Model—to help make language explicit in content area classrooms.

Both Lemke (1990) and Gibbons (2003) have argued that teachers should talk directly with students about scientific discourse, introduce semantic relationships among scientific terms, and give students more practice in speaking about science. They have recommended using informal or everyday speech initially so students understand the information and concepts being taught, and teaching the ELs the necessary technical terms, grammatical expressions, and discourse patterns (such as use of argumentation afterwards). A recent, small-scale experimental study of a four-hour web-based lesson supports those recommendations. Brown and Ryoo (2008), who gave fifth graders a researcher-developed assessment of photosynthesis using scientific language, found that students who were taught with a method that explained scientific concepts in everyday language before introducing scientific terms performed better than students who were taught with a method that used the scientific terms from the outset.

FIGURE 1.1 *Hiebert's Challenges and Assets of Learning Science Vocabulary (Hiebert, 2008)*

Challenges	*Assets*
1. Dense	1. Clear delineation of vocabulary
2. Conceptually difficult	2. Build-up of ideas
3. Central to text	3. Concepts can be taught thematically
4. General academic vocabulary	4. Many clear Spanish cognates
5. Not much time for science instruction	5. Potential for high levels of engagement

Hiebert (2008) offers a useful description of the challenges and assets that exist in learning science vocabulary. As shown in Figure 1.1, the first four challenges for educators to keep in mind are related to academic language teaching. By the end of the elementary grades, science vocabulary is often found in dense text. This means that many scientific terms may be found in one given paragraph. The words are more often conceptually difficult to understand. In other words, a reader can't rely on known information to determine a meaning; rather, he or she must be taught new information that in turn helps explain the meaning. Science vocabulary is not easy to skip over. If you encounter an unknown word in a science text, it is usually central to the meaning of the sentence and often the entire paragraph. Skipping over and reading on is not as likely to help in comprehension as it might in other types of text, such as stories. Science, like many content areas, also uses a high number of more general academic words, such as *determine*, *explain*, and *predict*, which we discussed earlier in this chapter. The fifth challenge of too little time for science instruction has been true across the United States, with the increased emphasis on math and reading time, particularly in elementary schools. But we are seeing some adjustments now that science is part of the battery of assessments that Title I schools need to take under NCLB.

Hiebert (2008) has also identified aspects of science vocabulary that may facilitate learning for our English learners. Most of the science-specific terms, such as *velocity*, *xylem*, and *igneous*, have clear definitions that when learned aid in comprehension. Further, science concepts are built and reviewed over time. Unlike stories read in language arts, which can include very different sets of vocabulary for each story, science texts reinforce words within a grade and as students move up the grades. Repeated exposure and use of the words assists in learning. Science words can be taught thematically also. This type of instruction helps students remember and retrieve new terms. Many scientific terms and general academic words in English have close cognates in Latin-based languages; moreover, a number of the terms are high-frequency words in Spanish, but low-frequency words in English, which can benefit our ELs who are speakers of Spanish. The fifth asset is less directly related to vocabulary development but is important nonetheless for success in science classes. Science instruction can be highly engaging. If students are engaged in lessons, they are more likely to learn. That is one reason why student engagement is an important feature in the SIOP® model.

Scott (1992) wrote "Language plays [roles] in science learning . . . science can be used to develop children's language, and . . . increased knowledge of language goes hand in hand with the development of scientific ideas" (p. ix). Researchers have found that students learn science better when they engage in literacy-related activities (Bredderman, 1983; Fellows, 1994; Holliday, Yore, & Alvermann, 1994; Rowe, 1996). In the classroom,

then, science and language become interdependent. “These reciprocal skills give teachers and students a unique leverage: by merging science and language in the classroom, teachers can help students learn both more effectively” (Short & Thier, 2006, p. 206).

There are myriad terms that are used in academic settings. As mentioned previously, some of these are used commonly across the curricula and others are content specific. The metaphor of bricks and mortar may be helpful for you here if you think of some words representing bricks, such as science content-specific words (e.g., *electromagnet, meiosis, calcium chloride*). The mortar refers to general academic words (e.g., *determine, represent, attribute, approximate*) (Dutro & Moran, 2003). Understanding both types of terms is often the key to accessing content for English learners. For example, while most students need to have terms related to science explicitly taught, English learners also require that general academic words be included in vocabulary instruction. In addition, science often utilizes words with multiple meanings (i.e., polysemous words) for specific purposes and students may know one meaning, but not the other. Consider *table*, *mass*, *wave*, and *property*. ELs are likely to know of tables and chairs, a religious mass, a wave of the hand, and property their family owns, but may not know the scientific usage of these terms. So those terms need specific attention as well.

As you plan for lessons that teach and provide practice in both science-specific academic language and more general academic language, use your teacher’s guides from your textbook to note the highlighted vocabulary, but consider other terms and phrases that may need to be taught. See Figure 1.2 by contributor Austin-Phillips for a breakdown of such terms and phrases. Also, you may use your state science content standards and English language proficiency standards to assist you in selecting the general academic language you need to teach and reinforce. Other resources include the “1,000 Most Frequent Words in Middle-Grades and High School Texts” and “Word Zones™ for 5586 Most Frequent Words,” which were collected by Hiebert (2005) and may be found online at www.textproject.org. For those of you who are high school teachers, you might also want to take a look at the Coxhead Academic Word List (Coxhead, 2000). [Available at http://www.victoria.ac.nz/lals/staff/Averil-Coxhead/awl/ and http://simple.wiktionary.org/wiki/Wiktionary:Academic_word_list]

While studying science, therefore, students are exposed to new terms that they are unlikely encounter in other subjects, general academic words that have use across the curriculum, and polysemous words for which they know a common meaning, but not the particular meaning used in the science context. Let’s take a look at the various terms that are present in a few sample science standards. The words that are science specific are **bolded**, general academic words are <u>underlined</u>, and the polysemous words are in *italics.* Some words, you will see, are specific to science and also polysemous, so students may think they know what the words mean, but do not know the definition for the purpose intended by these standards.

In Kindergarten through Grade 2:

- Students know how to <u>identify</u> **resources** from Earth that are used in everyday life and <u>understand</u> that many resources can be **conserved**.
- Students know ***solids***, ***liquids***, and ***gases*** have different ***properties***.
- Students know many <u>characteristics</u> of an **organism** are **inherited** from the parents. Some characteristics are <u>caused</u> or <u>influenced</u> <u>by</u> the **environment**.

FIGURE 1.2 *Austin-Phillips' Science Language Chart*

Grade Level Band	*Technical Words*	*Process Words*	*Phrases/Sentence Starters*
K–2	natural, seasonal, living, non-living, environment, human, plant, moon, sun	similar, different, draw, label, question, cycle	• I notice . . . • I see . . . • I wonder . . . • Why does . . .? • How does . . .? • I want to know how/why . . . • Some characteristics of ____ are . . . • Some similarities are . . . • Some differences are . . .
3–5	refract, reflect, rotation, revolution, solid, liquid, gas, motion	characteristics, relationship, distinguish, observe, procedure, impact, argument	• I noticed . . . • These are similar because . . . • These are different because . . . • The data shows . . . • _____ is impacted by _____ because . . .
Middle School	mass, volume, particles, matter, mixture, pure substance, phenomena, ecosystem, weathering, erosion, deposition	influence, technology, logical, collaborate, diagram, infer	• One observation I made during the experiment was . . . • I observed . . . From my observations I can infer . . . • My hypothesis/prediction is supported/rejected because . . . • In conclusion . . . • We found that . . . • Our research question was . . . • My opinion is . . .
High School	cell theory, atomic theory, plate tectonic theory, isotopes, agitation, catalyst, thermodynamics, convection	skeptical, system, analysis, transfer, reliable, investigate	• According to the data . . . • The hypothesis was supported/rejected because . . . • Current research demonstrates . . . • In conclusion . . . • If_____, then . . . • The data indicates . . . • Possibilities for further research include . . . • Sources of error include . . .

In Grades 3–5:

- Students will collect **data** in an investigation and analyze those data to develop a logical conclusion**.**
- Students know plants are the *primary source* of ***matter*** and ***energy*** entering most **food chains**.
- Students know **electrically charged** objects attract or repel each other.

In Grades 6–8:

- Students will *plan* and conduct investigations in which ***independent*** and ***dependent variables***, ***constants***, ***controls***, and repeated *trials* are identified.

- Students will investigate and understand how **organisms** adapt to **biotic** and **abiotic** *factors* in a **biome**.
- Students will investigate and understand various *models* of **atomic structure** including **Bohr** and ***Cloud*** (**quantum**) models.

In Grades 9–12:

- Students know how to determine the **molar mass** of a **molecule** from its **chemical formula** and a *table* of **atomic masses** and how to convert the ***mass*** of a **molecular** substance to ***moles***, number of **particles**, or volume of ***gas*** at standard temperature and *pressure*.
- Students will be able to define **probability** and describe how it helps explain the results of **genetic crosses**.
- Students know how to identify **transverse** and **longitudinal** ***waves*** in **mechanical media**, such as *springs* and ropes, and on the Earth (**seismic waves**).

As you can see, many of the underlined words may be used in other content areas as well, but students need to be explicitly taught their specialized meaning in a particular science course. For students who speak a Latin-based language such as Spanish, cognates will help in teaching a number of words. For example, *predict* in English is *predecir* in Spanish; *justify* in English is *justificar* in Spanish; *investigation* in English is *investigación* in Spanish. Science-specific words should be explicitly taught as part of each science lesson.

You should also be aware that the national standards for English language proficiency (ELP) clearly state that students need to learn about science language (TESOL, 2006). They are similar to the WIDA (World-class Instructional Design and Assessment) standards that have been adopted by 20 states. The science language standard is:

> **English language learners communicate information, ideas, and concepts necessary for academic success in the content area of science.**

Model performance indicators are provided at five proficiency levels across grade-level clusters (PreK–K, 1–2, 3–5, 6–8, and 9–12) for the four domains—speaking, reading, writing, and listening. Gottlieb and Lederman (2006) suggest ways that national and state science standards can be integrated with these national ELP standards for science language and explain how the model performance indicators for the standards adjust the language load on students according to their proficiency levels, yet teach the curricular content.

In Appendix B you will find a listing of academic science vocabulary words found in the national and state science standards. Your state's standards and domains may differ somewhat, but we hope this extensive list will assist you in your lesson and unit planning, and in the writing of your content and language objectives.

Why Do English Learners Have Difficulty with Academic Language?

Developing academic language has proven to be quite challenging for English learners. In fact, in a study that followed EL students' academic progress in U.S. schools, researchers found that the ELs actually regressed over time (Suarez-Orozco, Suarez-Orozco & Todorova,

2008). There are a multitude of influences that affect overall student learning, and academic language learning in particular. Some factors, such as poverty and transiency, are outside of the school's sphere of influence, but some factors are in our control, namely what happens instructionally for these students that facilitates or impedes their learning.

Many classrooms are devoid of the kinds of supports that assist students in their quest to learn new material in a new language. Since proficiency in English is the best predictor of academic success, it seems reasonable that teachers of English learners should spend a significant amount of time teaching the vocabulary required to understand the lesson's topic. However, in a study that observed 23 ethnically diverse classrooms, researchers found that in the core academic subject areas only 1.4% of instructional time was spent developing vocabulary knowledge (Scott, Jamison-Noel, & Asselin, 2003).

The lack of opportunity to develop oral language skills hinders students' progress in all subject areas. Passive learning—sitting quietly while listening to a teacher talk—does not encourage engagement. In order to acquire academic language, students need lessons that are meaningful and engaging and that provide ample opportunity to practice using language orally. Successful group work requires intentional planning and teaching students how to work with others effectively; teacher expectations need to be made clear. Grouping students in teams for discussion, using partners for specific tasks, and other planned configurations increase student engagement and oral language development.

Another related reason that ELs struggle is lack of access to the language and the subject matter. Think about a situation in which you hear another language spoken. It could be the salon where you get a hair cut or your favorite ethnic restaurant. Just because you regularly hear another language, are you learning it? Typically not. Likewise, many English learners sit in class and hear what amounts to "English noise." It doesn't make sense to them and thus, they are not learning other academic language or the content being taught. Without the kinds of practices that are promoted by the SIOP® Model, much of what happens during the school day is lost on English learners.

We must also consider the types of classroom cultures students have experienced in the past. As Lemke (1990) noted, competence in content classes requires more than mastery of the subject matter topics; it requires an understanding of and facility with the genres and conventions for spoken and written interaction and the skills to participate in class activities. Currently, many science classes incorporate inquiry lessons that are designed to engage students in discovering scientific principles and conducting science experiments in a manner similar to the methods scientists use. However, some ELs who are recent immigrants may never have experienced an inquiry lesson. They may never have had the opportunity to conduct an experiment by manipulating scientific equipment and materials. They may have learned science through rote memorization of teacher lectures or textbook chapters. Therefore, teachers will need to introduce these ELs to a new classroom culture in which students are expected to participate orally, work in cooperative groups, solve problems, conduct experiments, generate hypotheses, express opinions, and so forth. Because the communication patterns in class may be very different from those in the students' native culture, teachers need to engage in culturally responsive teaching (Bartolomé, 1998), being sensitive to and building upon culturally different ways of learning, behaving, and using language. Working together, respectfully, the students and teacher can create a classroom culture in which they will all feel comfortable and learning can advance.

Finally, some teachers have low expectations for EL students (Lee, 2005). They are not motivated to get to know the students, their cultures, or their families. Poor performance

is not only accepted, but expected. Rather than adjusting instruction so that it is meaningful to these students, teachers attribute lack of achievement to students' cultural background, limited English proficiency, and, sadly, ability. This attitude is unacceptable and staff who hold this view need to be re-educated in appropriate ways to teach these students and to learn that all students can reach high standards, although the pathways by which they attain them may vary.

How Can We Effectively Teach Academic Language with the Siop® Model?

In a recent synthesis of existing research on teaching English language and literacy to ELs in the elementary grades, the authors make five recommendations, one of which is to "Ensure that the development of formal or academic English is a key instructional goal for English learners, beginning in the primary grades." (Gersten, et al., 2007, pp. 26–27). Although few empirical studies have been conducted on the effects of academic language instruction, the central theme of the panel of researchers conducting the synthesis was the importance of intensive, interactive language practice that focuses on developing academic language. This recommendation was made based upon considerable expert opinion, with the caveat that additional research is still needed. Additional reports offer similar conclusions (Deussen, Autio, Miller, Lockwood, & Stewart, 2008; Goldenberg, 2008; Short & Fitzsimmons, 2007).

Because you are already familiar with the SIOP® Model, you know that effective instruction for English learners includes focused attention on and systematic implementation of the SIOP® Model's eight components and thirty features. The SIOP® Model has a dual purpose: to systematically and consistently teach both content and language in every lesson. Content and language objectives not only help focus the teacher throughout a lesson, but also (perhaps even more importantly) focus students on what they need to know and be able to do during and after each lesson as related to *both* content knowledge and language development. Therefore, you should use the SIOP® protocol to guide lesson design when selecting activities and approaches for teaching academic language in your science courses. (See Echevarria & Colburn, 2006, for a discussion of designing inquiry-based SIOP® science lessons.)

Academic Vocabulary

Within the SIOP® Model, we refer to academic vocabulary as having three elements (Echevarria, Vogt, & Short, 2008, p. 59). These include:

1. *Content Words*: These are key vocabulary words, technical terms, and concepts associated with a particular topic. Key vocabulary, such as *solubility, covalent bond, ecosystem, mitochondria, Punnett square,* and *velocity,* typically come from science texts as well as from other components of the curriculum. Obviously, you will need to introduce and teach key content vocabulary when teaching about plants and animals, physical science, earth science, biology, chemistry, and physics.
2. *Process/Function Words*: These are the words and phrases that have to do with functional language use, such as *how to make a hypothesis, provide evidence for a claim,*

state a conclusion, explain the effect, "state in your own words," summarize, ask a question, interpret, and so forth. They are general academic terms. Tasks that students are to accomplish during a lesson also fit into this category, and for English learners, their meanings may need to be taught explicitly. Examples include *list, explain, paraphrase, identify, create, monitor progress, define, share with a partner,* and so forth.

3. *Words and Word Parts That Teach English Structure*: These are words and word parts that enable students to learn new vocabulary, primarily based on English morphology. While instruction in this category generally falls under the responsibility of English-language arts teachers, we also encourage teachers of other content areas to be aware of the academic language of their own disciplines. The English-language arts (ELA) or English as a second language (ESL) teacher may teach the formation of the past tense (such as adding an *–ed* to regular verbs), yet you might reinforce past tense by pointing out that when we talk about scientific discoveries that happened in prior centuries, we use the past tense of English verbs, much like a history teacher might draw attention to past tense forms when discussing and reading about historical events. Similarly, when you give students written directions for lab experiments, you might point out that the steps tend to start with a verb, rather than a noun as found in basic sentences.

   ELA teachers will likely teach morphology (base words, roots, prefixes, suffixes), but you may teach many words with these word parts as key vocabulary (such as *in*vestiga*tion* or *bio*de*grad*able). Science lends itself especially well to activities with roots and affixes because so many scientific terms utilize these word parts. Think about the root *derm*, for instance. If we teach students it means "skin," it might help them figure out *epidermis*, *dermatology*, *pachyderm*, and *hypodermic*, especially if we teach the suffix *-ology* and the prefix *hypo-* too.

   For a usable and informative list of English word roots that provide the clue to more than 100,000 English words, refer to pages 60–61 of *Making Content Comprehensible for English Learners: The SIOP® Model* (Echevarria, Vogt, & Short, 2008). This is a must-have list for both elementary and secondary teachers in ALL curricular areas.

In sum, picture a stool with three legs. If one of the legs is broken, the stool will not function properly; it will not support a person who sits on it. From our experience, an English learner must have instruction in and practice with all three "legs" of academic vocabulary (content vocabulary, process/function words, and words/word parts that teach English structure) if they are going to develop the academic language they need to be successful students.

Zwiers (2008, p. 41) notes that "academic language doesn't grow on trees." Rather, explicit vocabulary instruction through a variety of approaches and activities provides English learners with multiple chances to learn, practice, and apply academic language (Stahl & Nagy, 2006). This requires teachers to provide comprehensible input (Krashen, 1985), as well as structured opportunities for students to produce academic language in their content classes. These enable English learners to negotiate meaning through confirming and disconfirming their understanding while they work and interact with others.

In addition to explicit vocabulary instruction, we need to provide a variety of scaffolds, including ones that provide context. Writing a list of science terms or pointing out

terms that are in bold print in the textbook only helps if students know what they mean. To create a context for learning new words, teachers should preteach the terms, explain them in ways that students can understand and relate to, and then show how the terms are used in the textbook or classroom discourse. Scaffolding involves providing enough support to students so that the learners gradually are able to be successful independently.

Another way of scaffolding academic English is by having word walls or posters displayed that show key terms with visuals, definitions and/or sentences that use the term in context. In Chapter 2, one technique describes signal word posters that help students focus on words related to comparison and contrast, or cause and effect, or other relationships. Certainly, older learners can work in groups to create these posters with mnemonics, including cartoons or other illustrations. These aids reduce the cognitive load for English learners so that they can focus on scientific theory and processes without having to remember their associated linguistic terms. As students refer to and use these posted academic language words and phrases, the terms will become internalized and will later be used independently by students.

If English learners have opportunities to read, write, and orally produce words during science lessons and in their history, math, and/or English classes, the words are reinforced. And, if this reinforcement occurs throughout each and every school day, one can assume that English learners' mastery of English will be accelerated, much like repeated practice with any new learning.

Oral Discourse

Researchers who have investigated the relationship between language and learning suggest that there should be more balance in student talk and teacher talk to promote meaningful language learning opportunities for English learners (Cazden, 2001; Echevarria, 1995; Saunders & Goldenberg, 1992; Tharp & Gallimore, 1988; Walqui, 2006). In order to achieve a better balance, teachers need to carefully analyze their own classroom interaction patterns, the way they formulate questions, how they provide students with academic feedback, and the opportunities they provide for students to engage in meaningful talk.

Not surprisingly, teacher questioning usually drives the type and quality of classroom discussions. The IRE/F pattern discussed previously is characterized by questions to which the teacher already knows the answer and results in the teacher unintentionally expecting students to "guess what I'm thinking" (Echevarria & Silver, 1995). In fact, researchers have found explicit, "right there" questions are used about 50% of the time in classrooms (Zwiers, 2008) and science "discussions" can devolve into a series of factual exchanges.

In contrast, open-ended questions that do not have quick "right" or "wrong" answers promote greater levels of thinking and expression. During science lessons, there should be more of an emphasis on promoting classroom discourse by students questioning one another, separating fact from opinion, reasoning rather than memorizing procedures or guessing outcomes, making connections or generalizations, conducting experiments and communicating observations, drawing conclusions. For example, questions such as "Compare a cactus with a rose bush. Which is more suitable for a garden in your backyard and why?" and "Explain why Newton's first law of motion is important to the automobile industry" not only engender higher-level thinking about scientific phenomena but also

provide an opportunity for students to grapple with ideas and express themselves using academic English.

The Interaction component in SIOP® Model promotes more student engagement in classroom discourse. The features of the Interaction component, which should be familiar to you, include:

- Frequent opportunities for interaction with and discussion between teachers and students and among students, which encourage elaborated responses about lesson concepts
- Grouping configurations that support language and content objectives of the lesson
- Sufficient wait time for student responses that is consistently provided
- Ample opportunities for students to clarify key concepts in L1 (Native language) as needed

These features promote balanced turn-taking between teachers and students, and among students, providing multiple opportunities for students to use academic English. Notice how each feature of Interaction encourages student talk. This is in considerable contrast to the discourse patterns typically found in both elementary and secondary classrooms.

Something as simple as having students turn to a partner and discuss an answer to a question first, before reporting out to the whole class, is an effective conversational technique, especially when the teacher circulates to monitor student responses. Speaking to a peer may be less threatening and also gets every student actively involved. Also, rather than responding to student answers with "Very good!" teachers who value conversation and discussion encourage elaborated responses with prompts such as "Can you tell us more about that?" or "What made you think of that?" or "Did anyone else have that idea?" or "Please explain how you figured that out."

Zwiers (2008, pp. 62–63) has classified comments teachers can make to enrich classroom talk; by using comments like these, a greater balance between student talk and teacher talk is achieved. Further, classroom interactions are less likely to result in an IRE/F pattern. Try using some of the comments below and see what happens to the interaction pattern in your own classroom!

To Prompt More Thinking

- You're on to something important. Keep going.
- You're on the right track. Tell us more.
- There is no right answer, so what would be your best answer?
- Can you connect that to something else you learned/saw/experienced?

To Fortify or Justify a Response

- That's a probable answer . . . How did you to that answer?
- What evidence do you have to support that claim?
- What is your opinion/impression of . . . Why?

To Report on an Investigation

- Tell us more about what you noticed.
- Describe your result.
- How is your hypothesis the same or different?

- What do you think caused that to happen?
- How else might you study the problem?
- Can you generalize this to another situation? How?

To See Other Points of View

- So you didn't get the result you expected. What do you think about that?
- If you were in that person's shoes, what would you have done?
- Would you have done it like that? Why or why not?

To Consider Consequences

- Should she have . . . ?
- What if he had not done that?
- Some people think that . . . is wrong/right. What do you think? Why?
- How can we apply this to real life?

A conversational approach is particularly well-suited to English learners who, after only a few years in school, often find themselves significantly behind their peers in most academic areas, especially when instruction is in English, usually because of low reading levels in English, weaker vocabulary knowledge, and underdeveloped oral language skills. Students benefit from a conversational approach in many ways because conversation provides:

- A context for learning in which language is expressed naturally through meaningful discussion
- Practice using oral language, which is a foundation for literacy skill development
- A means for students to express their thinking, and to clarify and fine-tune their ideas
- Time to process information and hear what others are thinking about
- An opportunity for teachers to model academic language, use content vocabulary appropriately, and, through think-alouds, model thinking processes and learning strategies
- Opportunities for students to participate as equal contributors to the discussion, which provides them with repetition of both linguistic terms and thinking processes, and results in their eventual acquisition and internalization for future use

A rich discussion, or conversational approach, has advantages for teachers as well, including the following:

- Through discussion, a teacher can more naturally activate students' background knowledge and assess their prior learning
- When working in small groups with each student participating in a discussion, teachers are better able to gauge student understanding of the lesson's concepts, tasks, and terminology, as well as discern areas of weakness.
- When teachers and students interact together, a supportive environment is fostered, which builds teacher–student rapport.

When contemplating the advantages of a more conversational approach to teaching, think about your own learning. In nearly all cases it takes multiple exposures to new terms, concepts, and information before you can use them independently. If you talk with others about the concepts and information you are learning, you're more likely to remember them. English learners require even more repetition and redundancy to improve their language skills. When they have repeated opportunities to improve their oral language proficiency, ELs are more likely to use English, and more frequent use results in increased proficiency (Saunders & Goldenberg, in press). With improved proficiency, ELs are more adept at participating in class discussions. Discussion and interaction push learners to think quickly, respond, construct sentences, put their thoughts into words, and ask for clarification through classroom dialogue. Discussion also allows students to see how other people think and use language to describe their thinking (Zwiers, 2008).

Productive discussion can take place in whole class settings, but it is more likely that small groups will facilitate the kind of high-quality interaction that benefits English learners. Working to express ideas and answers to questions in a new language can be intimidating for students of all ages. Small group work allows them to try out their ideas in a low-stress setting and to gauge how similar their ideas are to those of their peers. Working with partners, triads, or in a small group also provides a chance to process and articulate new information with less pressure than a whole class setting may create.

Earlier in this chapter, you read an interaction between a teacher and her students in which the IRE/F pattern prevailed. In contrast, read the following interaction from an eighth grade physical science class that was part of a SIOP® research study,[2] and reflect on the differences in the two classroom interaction patterns:

MS. ARMSTRONG: We saw the video clip and have been discussing the differences between chemical and physical change. Are you ready for your Round Robin activity?

STUDENTS: Yes. Yup. Uh hmm.

MS. ARMSTRONG: Okay, supply keepers come get your team's folders. This is Round Robin Classifying. Who remembers what to do?

ALYSHA: We number our papers 1–6. We get an index card with one of those numbers and answer the question. Then we pass the card to the next student and get a new card passed to us.

MS. ARMSTRONG: Do you agree or disagree with Alysha?

JORGE: I agree. It's like what we did last week with the ionic and covalent bonds.

MS. ARMSTRONG: Can you add any more to the directions?

JORGE: Well, we have only 1 minute to answer each one.

MS. ARMSTRONG: Okay. I'll tell you when to switch. Tick tock like a clock. You pass the cards clockwise.

[Students work in their teams answering the questions. Teacher calls out "Switch" after one minute passes and continues to do so until each student has a chance to answer all six questions.]

[2]All names are pseudonyms.

MS. ARMSTRONG: Now have a Roundtable discussion for five minutes. At your tables, what should I hear?

STUDENTS: Accountable talk.

MS. ARMSTRONG: Right. I want you thinking like a scientist.

[Green Team]

SONIA: I think the marshmallow is a chemical change.

TYRONE: Can you tell us why?

SONIA: Well, it changed temperature over the fire and got a hard crust on it.

ANDRES: I agree, it became a new substance.

TYRONE: Do we all agree? [Students nod.] Okay what about the water vapor?

ANDRES: The water is now a gas. That's a new substance too. [Teacher moves to this group and listens.]

DOLORES: Wait, I don't think that's right.

MS. ARMSTRONG: What's your evidence, Dolores?

DOLORES: Isn't water vapor still water? It's a gas but it's water too.

TYRONE: Can we think of a way to decide?

STEFANIE: When I cook beans, I put them in water in a pot. The water gets hot with bubbles. Water vapor goes up. But if I put the top on, drops of water are inside the top.

DOLORES: I see that too when I cook.

MS. ARMSTRONG: You're thinking outside the box.

ANDRES: So I'm wrong?

TYRONE: Yeah man, but it's okay. This isn't easy.

This class included ELs at all proficiency levels as well as native English speakers. Although all of your students may not sound exactly like these students, we know it is possible for them to participate in robust conversations as these students did. Much of the participation is internalized because the teacher has spent time with the class teaching accountable academic talk, has taught them routines for listening and responding to others, has encouraged them to respect one another's opinions, and has modeled how to justify an argument.

Note how the teacher facilitates this discussion with very few words: just some directions and then comprehension probes and careful listening. Teaching students to share conversational control and stepping back, trusting them to get the job done, takes some risk-taking on the part of the teacher and practice on the part of students, who may be used to just answering questions with monosyllabic responses. Simply telling students to "have a discussion among yourselves" will be less successful. We need to teach students how to engage in meaningful conversation and discussion and provide the support they need to do it well. Rather than sitting as "quiet cornstalks," students, including English learners, can learn to express themselves, support their viewpoints, advocate their positions, and defend their positions. When this occurs, we establish a classroom environment in which conversational control is shared among teachers and students alike.

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Concluding Thoughts

Proficiency in English is the best predictor of academic success, and understanding academic language is an important part of overall English proficiency. In this chapter we have discussed what academic language is, why it is important, and how it can be developed in science classes and across the curriculum. In all content areas, teachers need to plan to explicitly teach both content area terms and general academic terms so that English learners can fully participate in lessons; acquire knowledge about concepts, theories, and processes of science; meet science standards; and increase their academic language proficiency.

For our students to be achieve academically in science, they need to have practice with language skills that allows them to back up claims with evidence, be more detailed in their observations, use persuasive language compellingly in arguments, and compare events or points of view. When you teach students how to participate in classroom conversations and structured discussions, and how to read and write and think like a scientist, you not only improve their English skills but also prepare them for the academic language skills used in school and in professional settings. Teachers need to ensure that students internalize scientific habits of mind, such as using evidence to separate opinion from fact. If students are to become adults capable of making informed choices and taking effective action in the twenty-first century, then they must absorb those habits into their regular patterns of thought so the habits endure long after the students have graduated. Once they are scientifically literate, students will possess a set of skills that merges the knowledge of science concepts, facts, and processes with the ability to use language to articulate, converse about, and debate those ideas.

In the lesson plans and units that appear in Chapters 4–8, you will see a variety of instructional techniques and activities for teaching, practicing, and using academic language in science classrooms. As you read the lesson plans, reflect on why particular activities were selected for the respective content and language objectives. Additional resources for selecting effective activities that develop academic language and content knowledge include: Buehl's *Classroom Strategies for Interactive Learning* (2001); Vogt and Echevarria's *99 Ideas and Activities for Teaching English Learners with the SIOP® Model* (2008); Reiss's *102 Content Strategies for English Language Learners* (2008), and Marzano and Pickering's *Building Academic Vocabulary: Teacher's Manual* (2005). Secondary teachers will also find the following books, among many others, to be helpful: Zwiers's *Building Academic Language: Essential Practices for Content Classrooms (Grades 5-12)* (2008) and *Developing Academic Thinking Skills in Grades 6-12: A Handbook of Multiple Intelligence Activities* (2004); Fisher and Frey's *Word Wise and Content Rich: Five Essential Steps to Teaching Academic Vocabulary* (2008), and Cloud, Genesee and Hamayan's *Literacy Instruction for English Language Learners* (2009).