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RESEARCH REPORT

The Language Demands of Science Reading in Middle School

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The language used to construct knowledge, beliefs, and worldviews in school science is distinct from the social language that students use in their everyday ordinary life. This difference is a major source of reading difficulty for many students, especially struggling readers and English-language learners. This article identifies some of the linguistic challenges involved in reading middle-school science texts and suggests several teaching strategies to help students cope with these challenges. It is argued that explicit attention to the unique language of school science should be an integral part of science literacy pedagogy.

Introduction

> Thus, educators need to focus on the language of science, not just thinking and doing science inquiries. (Hand et al., 2003, p. 611)

Middle school (Grades 6–8, ages 11–14 in the USA) constitutes a period of schooling when students are regularly required to read and write in content areas such as science and history. Unlike in the lower elementary grades where instruction typically focuses on developing basic reading skills and strategies (e.g., phonological awareness, decoding, fluency, predicting, retelling), ideally students in the upper elementary grades and beyond are in the "reading-to-learn" stage when they are supposed to use reading/writing to gain content knowledge from academic subjects while simultaneously developing more advanced reading/writing skills (Chall, 1996). This transition, from the so-called "learning to read" in the early elementary grades to "reading to learn" in the upper elementary grades and beyond, is not smooth for many students, however. According to Chall, Jacobs, and Baldwin (1990), students in the fourth grade often show a sudden drop in their literacy achievement and this

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decline grows steeper as students advance to middle and high schools—a phenomenon now widely known as the "fourth grade slump" or "fourth grade cliff."

Scholars have speculated as to what causes this "fourth grade slump" phenomenon. One of the most often cited reasons is the shift in curricular materials. In the early elementary grades, students are exposed to reading materials that are predominantly narrative and filled with dialogues; whereas in upper elementary grades and beyond, expository texts in curriculum subjects are the main literacy staples. It is believed that a lack of familiarity with expository language is at least in part responsible for students' reading/writing problems beyond the elementary grades. In fact, scholars (e.g., Christie, 1998; Hammond, 1990) have suggested that the language of storybooks in the early elementary grades is closer to the ordinary language that children use in everyday social interaction and it is thus more familiar and comfortable to students. On the other hand, the expository, or specialist, language of academic subjects, such as the language of school science, is distinct from the everyday language of ordinary life and it thus appears less familiar and more alienating to students (Fang, 2005; Schleppegrell, 2004; Unsworth, 1997).

How is the expository language of curricular content areas different from the everyday language of ordinary life? What is it about the expository language that makes it so challenging for students, especially struggling readers and English-language learners, to understand and use? In this article, I describe some salient features of one type of expository language—the language of school science (LSS), highlighting how it differs from children's everyday language (EL)—and discuss the challenges these features present to middle-school students in terms of reading comprehension. Next, I describe several classroom-based strategies that teachers can use to promote students' understanding and use of LSS. I conclude with a call for explicit attention to LSS as an integral part of a broader conception of literacy pedagogy in the content area.

Before proceeding further, I should note that while I recognize that LSS can be both oral and written, I decided to limit my discussion to the written language of school science, particularly that of science textbooks, because of its significance in school curriculum (Good, 1993; Weiss, Banilower, McMahon, & Smith, 2001) and of the unique challenges it presents to students (Fang, 2005). Moreover, while I recognize the multi-modal nature of today's science texts, for purpose of this article I chose to focus on language and ignore other communication systems (e.g., image, diagram, formula, charts), which are also important in the design of meaning in contemporary science (see, for example, Lemke, 1998). My focus on written school science is motivated by recent arguments that the development of modern western science is dependent on written text and that the fundamental sense of literacy—the ability to read and write the language of science—is central to scientific literacy (Norris & Phillips, 2003).

The Linguistic Challenges of Science Reading

Science is a form of culture with its own language (Gee, 2004; Roth & Lawless, 2002). The language of science has evolved, for functional reasons, from everyday language of ordinary life in order to meet the needs of scientific methods as well as those of scientific arguments and theories (Halliday & Martin, 1993). It contains unique lexicon, semantics, and syntax. This specialized grammar shapes, and is shaped by, the communal practices of the discipline (Bazerman, 1988). It allows scientists to conduct special kinds of semiotic and cognitive work, such as establishing clear links among claims, warrants, and evidence in order to develop scientific theories; adopting a critical stance in reading and evaluating scientific arguments; and writing to generate new knowledge and to communicate about scientific inquiries, procedures, and understandings (Yore et al., 2004). Although the science taught in school differs from actual science (Reif & Larkin, 1991), as a recontextualized version of science proper for pedagogical purposes, school science inherits essential properties of professional science discourse, such as informational density, technicality, abstraction, and authoritativeness (Fang, 2005). Therefore, developing control over the LSS is crucial for success in not only "doing schools," but "being scientific."

In the following, I describe a number of key features of LSS at the word, sentence, and discourse levels, spotlighting the comprehension challenges that these features present to middle-school students. I concur with Perera that it is necessary:

> to draw attention in as precise a way as possible to areas of difficulty so that teachers are able to offer precise help and guidance to their pupils as they tackle the demanding kind of formal language that is found in subject text books. (1982, pp. 117–118)

My discussion is based on my own experience with helping U.S. middle-school science teachers infuse reading and reading instruction into their classrooms (e.g., Fang, Lamme, & Pringle, 2005) and on the recent scholarship on science genres and registers (e.g., Halliday & Martin, 1993; Martin & Veel, 1998). The categories of linguistic features were derived primarily from the work of applied linguists who have explored the language demands of schooling (e.g., Fang, 2005; Perera, 1984; Schleppegrell, 2004; Unsworth, 2001). The examples were drawn from, unless otherwise noted, the textbooks used in the classrooms where I conducted my reading/science integration project: *Science Voyages* (Glencoe/McGraw-Hill, 2000) and *Science Explorer* (Prentice Hall, 2001), which happen to be two major science textbooks widely used in U.S. middle schools (see Weiss et al., 2001). Despite criticisms of textbooks (e.g., Guzzetti, Hynd, Williams, & Skeels, 1995; Kesidou & Roseman, 2002) and concomitant popularity of trade books in science classrooms (e.g., Giorgis & Hartman, 2000; Moore & Binz, 2002), science textbooks have improved qualitatively over the years and remain a major source of curricular decisions and reading materials in many American schools (Holliday, 2004). According to a recent national survey (Weiss et al., 2001), for example, 90% of middle-school science classes use one or two textbooks, with two publishers accounting for nearly two-thirds of the textbooks used. Given the importance and continuing predominance of textbooks in today's middle-school science curriculum, attention is warranted to the comprehension challenges that textbook language presents to students. As Holliday (2004) has argued, the opportunity to read demanding documents like textbooks is essential in preparation for later years of schooling and future professional careers.

Technical Vocabulary

One obvious feature of LSS is that it contains technical words that rarely occur in children's everyday informal spoken interaction. These technical terms are important for accurately conveying the specialized knowledge of science. They enable scientists to construct classes and categories and to establish taxonomic relationships among entities in the natural world. In the following two examples, "*deciduous*" and "*shearing*" are technical terms. In Extract 1, "*deciduous*" means the ability to shed leaves and grow new ones each year. It denotes a type of forest that is distinct from the rain forest. In Extract 2, "*shearing*" means stress that pushes a mass of rock in two opposite directions. It denotes a particular kind of stress, different from the other types of stress (i.e., *tension, compression*) that occur in the crust of the Earth. Thus, both words give precise meanings to their domains and cannot simply be replaced with the more commonsensical terms (e.g., *temporary, stress*) without loss of semantic accuracy and technicality, which are hallmark features of science.

1. *Deciduous* forests receive enough rain to support the growth of trees and other plants, at least 50 cm per year.
2. *Shearing* can cause rock to break and slip apart or to change its shape.

Technical terms are often multi-morphemic, many of which have Latin and/or Greek origins (e.g., *compressional = com + press + ion + al*; *microorganisms = micro + organ + ism + s*; *protostar = proto + star*; *anthropoda = anthro + poda*; *rhodophyta = rhodo + phyta*). They are typically set in bold face and explained/illustrated in science textbooks. They may also be indexed or defined in appended glossaries. In addition, they are often the focus of vocabulary and comprehension exercises. However, significant comprehension challenges can still arise when there is a heavy concentration of technical terms within a sentence, as Extract 3 shows. With technical terms constituting over one-third of its total words, the sentence has high density of information and can be overwhelming to students, even the proficient readers.

3. *Protozoans* that move using *flagella* are called *flagellates* and belong to the *phylum Zoomastigina*.

Ordinary Words with Non-vernacular Meanings or Usages

Not only does technical vocabulary pose comprehension challenges, ordinary words, when used in non-commonsensical or metaphorical ways, can also be a source of reading difficulty. Most words in the English language have multiple meanings. Words like "*school*," "*fault*," and "*volume*" are common in children's everyday vocabulary. However, when these words are used in the specialized discipline of science, as in Extracts 4–6, they usually mean something different from their vernacular senses, but students are often unaware of these additional meanings. This can be especially frustrating to some students because they can decode the words, but the meanings they assign to these words often do not enable them to comprehend successfully.

4. Fishes that swim in *schools* are often safer than fishes that swim alone, because it is harder for predators to see and select an individual fish. (groups vs educational institutions)
5. How rocks move along a *fault* depends on how much friction there is between the opposite sides of the *fault*. (break in the continuity of rock formation vs responsibility for a mistake, failure, or act of wrongdoing)
6. A liter is a measurement of liquid *volume*. (the amount of space an object occupies vs loudness of sound)

Another potential problem for reading comprehension stems from words that can serve multiple grammatical functions, one of which is more common in everyday language whereas others are rarely encountered in daily spoken language. For example, the second "*result*" in Extract 7 and the second "*flowers*" in Extract 8 are used in their usual senses as a noun. However, when these same words are used in their non-vernacular senses as a verb, as in the first sentences of Extracts 7 and 8, they can cause confusion. Similarly, the word "*young*" in Extract 9 is often used as an adjective in everyday language (e.g., *young mammals*), but rarely as a noun referring to a class or group of things. Some students, for example, find "*young milk*" baffling.

7. The hybrid organism that *results* is bred to have the best traits from both parents. For example, a farmer might cross corn that produces many kernels with corn that is resistant to disease. The *result* might be a hybrid corn plant with both of the desired traits.
8. An angiosperm is a vascular plant that *flowers* and has a fruit that contains seeds. The fruit develops from a part or parts of one or more *flowers*.
9. A mammal is a warm-blooded vertebrate that feeds its *young* milk.

Prepositions, Conjunctions, and Pronouns

It is not just content words (e.g., nouns, adjectives, verbs) that can be problematic. Grammatical words, such as prepositions, conjunctions, and pronouns, also have the potential to cause problems in reading comprehension. For example, the preposition "*on*" in Extract 10 does not convey its usual sense of space (meaning "*above*"), but rather connotes reliance and dependency.

10. An animal in hibernation survives *on* stored body fat.

Similarly, the conjunction "*or*" commonly denotes choices or alternates, as in Extract 11, but in science it is also used to introduce words/phrases that define, paraphrase, or synthesize a preceding term. In the latter instances, "*or*" is usually preceded by a comma. For example, "*or*" in Extracts 12 and 13 introduces "*distance above sea level*" and "*physical appearances*," which paraphrase the more technical/abstract terms of "*elevation*" and "*phenotypes*," respectively. The "*or*" in Extracts 14 and 15, on the other hand, introduces more abstract and technical terms (*magma*, *25 percent*) that theorize more commonsensical phrases (*molten material*, *1 in 4*).

11. A vaccine is a substance that stimulates the body to produce chemicals that destroy viruses *or* bacteria.
12. A region's elevation, *or* distance above sea level, also has an influence on temperature.
13. As with tall and short pea plants, these human traits have two distinctly different phenotypes, *or* physical appearances.
14. Volcano is a weak spot in the crust where molten material, *or* magma, comes to the surface.
15. The probability that an offspring will be TT is 1 in 4, *or* 25 percent.

Another grammatical word that often causes headaches for students is the conjunction "*while*," which can construe multiple logical relations. In Extract 16, "*while*" can be considered as either a temporal conjunction (meaning "*when*"/"*at the time*") or conditional conjunction (meaning "*if*"). In Extract 17, it is used as a concessive conjunction, meaning "*although*"; and in Extract 18 it is used as a contrastive/adversative conjunction, meaning "*but*". Figuring out these different logical relations that "*while*" construes is not easy and can be frustrating for struggling readers who may not have the extent of background knowledge and experience that proficient readers possess.

16. The virus that causes cold sores in humans is an example of a hidden virus. *While* hidden, the virus causes no symptoms.
17. *While* there is much yet to learn about how migrating animals find their way, scientists have discovered that animals use sight, taste, and other senses, including some that humans do not have.
18. The cormorants on the mainland were able to fly, *while* those on the Galapagos Islands were unable to fly.

"*Which*," a relative pronoun, also has the potential to cause comprehension difficulties for non-proficient readers. In science texts, "*which*" can be used in non-restrictive clauses to provide more information on a preceding nominal group or clause. Sometimes, it refers to the noun or noun phrase immediately preceding it; other times, it refers to "the whole of the primary clause or some part of it that is more than a nominal group" (Halliday & Matthiessen, 2004, p. 400). Determining exactly what the relative pronoun refers to may not be easy for some students. In Extract 19, for example, "*which*" refers to the noun immediately preceding it (*spores*). In Extract 20, it refers to the noun phrase "*increases in ocean temperature*," rather than simply "*ocean temperature*." In Extract 21, "*which*" refers to the clause immediately preceding it (*the environment is humid*), not just "*environment*." Being able to accurately identify the referent of "*which*" is critical to understanding the message in the sentence.

19. The sporophyte produces spores, *which* develop into the gameophyte.
20. Satellite images can also detect increases in ocean temperatures, *which* may put an area at risk for red tide.
21. Dr. Benjamin sees a lot of skin infections caused by fungi because the environment is humid, *which* promotes the growth of fungus.

Ellipsis

A further source of difficulty in reading science texts is ellipsis; that is, the omission of words, phrases, or clauses. Ellipsis is an important feature of written English language in general (Perera, 1984), because it enables writers to avoid unnecessary redundancy. Written science is no exception. This pursuit of linguistic economy can, however, create problems for some struggling readers who may still be in the process of developing more mature syntactic structures. In Extract 22, for example, the omission of "*able to open the tough pods*" at the end of the sentence can leave some students lost.

22. Finches with larger and stronger beaks were better able to open the tough pods than were finches with smaller, weaker beaks [ABLE TO OPEN THE TOUGH PODS].

In science texts, as in other academic texts, when the relative pronoun "*that*" is used to introduce an embedded clause, it is often elided. This omission can disrupt students' reading fluency and cause confusion. For example, in Extract 23, the elision of "*that*" after "*but*" conceals the second embedded clause, which modifies "*a biome*" and runs parallel to the first embedded clause that also modifies "*a biome*" (*... that receives little precipitation*). In Extract 24, the deletion of "*that*" tends to cause student readers to chunk incorrectly, because the embedded clause is not readily apparent. In fact, some students are confused by the presence of three verbs in the main clause (*the water vapor it <u>contains</u> <u>cools</u> and <u>condenses</u> as rain*), not knowing that the first verb goes with the embedded clause "*it contains*" to modify "*the water vapor,*" whereas the second and third verbs (*cools, condenses*) go with "*the water vapor.*"

23. At latitudes surrounding the north pole lies a biome that receives little precipitation but [THAT] is covered with ice most of the year.
24. When the air reaches a high enough altitude in the atmosphere, the water vapor [THAT] it contains cools and condenses as rain.

Sometimes, both relative pronouns (*that, which, who*) and auxiliary verbs (*be*) are omitted, resulting in embedded clauses introduced by "*-ed*" or "*-ing*" verbs, as in Extracts 25–27. Struggling readers, especially inexperienced English-language learners, often mistake these verbs as the verb for the subject of the sentence. In Extract 25, for example, some students tend to misidentify the word "*called*" as the main verb for the subject "*a diagram,*" so that when they see the present tense verb "*shows*" later in the sentence they become confused. In Extract 26, the main verb for the sentence is "*compare,*" with the other three verbs in past perfect tense (*produced, taken, suspected of*) introducing embedded clauses to expand information on "*the pattern,*" "*DNA,*" and "*people,*" respectively. The use of these unmarked embedded clauses makes the sentence both concise and compact. Similarly, in Extract 27, the embedded clause, "*lacking in protein, minerals, and vitamins,*" is used to expand information on the noun "*a diet,*" for which "*prevent*" is the main verb. When the relative pronoun (*that*) is inserted, the structure of the sentence becomes more transparent and thus comprehensible: "*A diet THAT lacks in protein, minerals, and vitamins can prevent a person from growing to his/her potential maximum height.*"

25. A diagram [THAT IS] called an energy pyramid shows the amount of energy that moves from one feeding level to another in a food web.
26. The DNA pattern can then be compared to the pattern [THAT IS] *produced* by DNA [THAT IS] *taken* from people [WHO ARE] *suspected of* committing the crime.
27. A diet *lacking in protein, minerals, and vitamins* can prevent a person from growing to his/her potential maximum height.

Subordinate Clauses

Subordinate clauses are those whose existence is dependent on the main clause. Unlike embedded clauses, they are not part of another clause and are typically introduced by conjunctions (e.g., *while, because, if, as*). Subordinate clauses can become a source of reading difficulty when their subjects and auxiliary verbs are removed for the sake of linguistic economy, as Extracts 28–31 demonstrate. One challenge in reading sentences with such elided subordinate clauses, also known more technically as "non-finite clauses," is to accurately identify their subjects. In Extract 28, for example, the elided subordinate clause "*Once fertilized*" means "*Once [reptile eggs are (have been)] fertilized.*" The subject for the subordinate clause is the same as that for the main clause. The verb in the elided subordinate clause can be in either "*-ed*" or "*-ing*" form. When it is in the "*-ed*" form, passive voice is implied, meaning that the subject is the recipient of action, as in Extracts 28 and 29. When the verb is in the "*–ing*" form, active voice is implied, meaning that the subject is the actor, as in Extracts 30 and 31. In Extract 30, for instance, the elided subordinate clause "*while still providing energy for a region to grow*" means "*while smaller dams still provide energy for a region to grow.*" The distance of the verb (*providing*) to its implied subject (*smaller dams*) can cause comprehension problems for some readers.

28. *Once fertilized,* reptile eggs have another advantage over amphibian eggs.
29. *When hatched,* the young reptiles are fully developed.
30. Smaller dams uproot fewer people and do less harm to the environment, *while still providing energy for a region to grow.*
31. *When soaring,* birds rise up into the sky on currents of warm air.

In some subordinate clauses, not only are the subject and auxiliary verb left out, but the conjunction that is often used to introduce the subordinate clause is also omitted. This results in subordinate clauses beginning with "*-ed*" or "*-ing*" verbs, as in Extracts 32–34. In these cases, the nature of logical ties between the subordinate clause and the main clause can become hidden, thus hindering comprehension. Readers will have to supply the logical–semantic links based on prior knowledge and/or the textual context. For example, in Extract 32, "*Given time*" can be said to introduce a conditional clause (*if decomposers are given time*). In Extract 33, a causal relationship is implicated in the subordinate clause. In Extract 34, "*forming two cells*" is best interpreted as realizing a consequential link to the main clause.

32. *Given time*, decomposers can decay the entire body of a large animal that scavengers missed.
33. *Alarmed by the fire and the destruction it caused*, people in Ohio began a massive campaign to clean up the Cuyahoga.
34. A single cell divides, *forming two cells.*

With- Prepositional Phrases

The preposition phrase introduced by "*with*" is another grammatical resource that enables economy in written text. As one kind of "grammatical metaphor" (Halliday & Mattiessen, 2004), which involves a transference of meaning from one grammatical category (e.g., clause and verb/ adjective) to another (e.g., prepositional phrase and noun), *with-* prepositional phrases are often used in place of subordinate or embedded clauses in science texts. This linguistic economy results in the concealment of the logical–semantic connection between the prepositional phrase and the main clause. Such implicit links will have to be inferred from the textual context and/ or prior knowledge. The uncovering of these links can, however, be a formidable task for inexperienced readers. For example, in Extract 35, the *with-* prepositional phrase can be interpreted as construing conditional (*If there are no jaguars to eat them*), causal (*Because there are no jaguars to eat them*), or temporal (*When there are no jaguars to eat them*) relations to the main clause. The *with-* prepositional phrase in Extract 36 gives a reason for why birds are considered the most diverse land dwelling vertebrates. In Extract 37, the *with-* prepositional phrase can be interpreted as describing the means through which sperms are deposited. However, it can also be viewed as providing a causal link (i.e., because of internal fertilization) to the main clause. Finally, in Extract 38, both conditional (*if storms travel from southwest to northeast*) and temporal (*at the time storms travel from southwest to northeast*) interpretations of the prepositional phrase are plausible. The ambiguity that results from the use of *with-* prepositional phrase in lieu of a clause, which is more congruent (i.e., common) in everyday language, can thus frustrate developing readers.

35. *With no jaguars to eat them*, the number of anteaters might increase.
36. *With almost 10,000 species*, birds are the most diverse land dwelling vertebrates.
37. *With internal fertilization*, sperms are deposited directly into the female's body.
38. A squall line of thunderstorms is likely to form, *with storms traveling from southwest to northeast.*

Abstract Nouns

Unlike everyday language, scientific language theorizes concrete experiences of ordinary life. Such theorizing involves turning concrete events (as expressed by verbs) and attributes (as expressed by adjectives) into abstract entities (as expressed by nouns), which can then become the subject to be further examined. This transformation of grammar, from verbs or adjectives into nouns, is called "nominalization." Also a kind of grammatical metaphor, nominalized phrases abstract away from immediate, lived experiences in order to build abstractions, generalizations, and arguments (Christie, 2001). They allow scientists to construct hierarchies of technical terms; to expand the meaning of things via numbering, describing, classifying, and qualifying them; and to synthesize previously stated information so that it can be taken up for further discussion in the text (Halliday & Matthiessen, 2004; Martin & Rose, 2003). For example, in Extract 39, the events in the first two sentences (i.e., cell divides and then further divides) are summarized into an abstract noun phrase "*this process of cell division*," which becomes the subject of the third sentence. Similarly, the phenomena described in the second and third sentences of Extract 40 are subsequently synthesized into an abstract noun "*this situation*," which is taken up in the fourth sentence. In Extract 41, the bending of light waves in the first sentence is referred to more technically as "*light diffraction*" in the second sentence. In Extract 42, the phenomena described in the first two sentences become "*the tumbling and splashing of swiftly flowing water*," a highly distilled and abstract noun phrase that becomes the subject of ensuing discussion. These examples suggest that nominalization is a particularly useful and effective grammatical resource for presentation of information, development of argument, and structuring of text in science. Readers who understand how nominalization works in scientific discourse would be in a better position to figure out the meaning of abstract nouns (e.g., *diffraction*) from the textual context.

39. A single cell divides, forming two cells. Then two cells divide, forming four, and so on. *This process of cell division* does not occur only in pumpkins, though.
40. In some places, the two high tides and two low tides are easy to observe each day. But in other places, the range between the water levels is less dramatic. One set of tides may even be so minimal that there appears to be only one high tide and one low tide per day. *This situation* is common along the coasts of Texas and Western Florida, due to the gradual slope of the ocean floor in the Gulf of Mexico.
41. As a matter of fact, light waves do bend around the edges of an open door. You can see some effects of *light diffraction* when you view a bright light through a small slit such as the one between two pencils held together.
42. The faster a stream flows, the clearer its water tends to be and the higher its oxygen content. Swift currents quickly wash loose particles downstream, leaving a rocky or gravelly bottom. *The tumbling and splashing of swiftly flowing water* mixes in air from the atmosphere, increasing the oxygen content of the water.

Considerable comprehension problem may arise when a sentence is packed with abstract nouns. In both Extracts 43 and 44, for example, four nominalized, highly distilled phrases (italicized) are used, making it exceedingly difficult for even the proficient readers to grasp the meaning of the sentences. It is no wonder that many

Table 1. Everyday language (EL) realization of the language of school science (LSS)

LSS	EL
Poor soil management	Soil is not treated properly.
Erosion	Soil is washed away slowly.
Nutrient depletion	Use up nutrients
Desertification	The land dries out and becomes a desert.
Methods of waste disposal	How to get rid of waste
Burial in landfills	Bury the waste in landfills
Incineration	Burn the waste
Breakdown	Break the waste down into its components

adolescent learners are turned off by texts like these. The more congruent, everyday language renditions of these nominalized phrases appear in Table 1.

43. *Poor soil management* can result in three problems: *erosion*, *nutrient depletion*, and *desertification.*
44. *Methods of waste disposal* include burial in *landfills*, *incineration*, and *breakdown* by living organism.

It is important to note that nominalization often involves more than just rewording. It is also a process of re-semanticizing, or re-meaning (Halliday, 1998). As demonstrated earlier, when a clause (or chunks of text) is condensed into a noun phrase, much of the semantic information becomes hidden. The knowledge that is presented through the nominalized phrase becomes much more distilled and, consequently, often conceptually more abstract. For example, "*this situation*" in Extract 40 encapsulates detailed information presented in the previous two sentences that will have to be recovered in order to enable true understanding of the fourth sentence. Thus, nominalization tends to obscure meaning. Readers will have to excavate the "concealed" meaning and resolve ambiguities in order to gain full understanding.

Lengthy Nouns

Like the professional language of science, LSS also has a high density of information. This density is achieved in part through the use of extended noun phrases (Unsworth, 1997), which compress information that would normally take several clauses to convey in everyday language. For example, the sentence "*A tornado is* <u>*a rapidly whirling, funnel-shaped cloud that reaches down from a storm cloud to touch Earth's surface*</u>" (lengthy noun underlined) is typically expressed in everyday language as "*A tornado is a kind of cloud. It is shaped like a funnel and moves very quickly. It reaches down from a storm cloud to touch Earth's surface.*" Science is a discipline aimed at describing, explaining, analyzing, classifying, comparing, generalizing, hypothesizing, theorizing, and arguing about the phenomena in the natural world. Extended noun phrases, along with relational verbs (e.g., *be*), are a key grammatical resource that enables scientists to get the job done.

The nouns used as subjects and/or objects of the sentences in science can sometimes be very long. These lengthy noun phrases pose formidable challenges for comprehension. When used as either subject or object, as in Extracts 45 and 46, they create an imbalanced syntactic structure, which can hinder sentence processing. When used as both subject and object in a single sentence, as in Extracts 47 and 48, they substantially increase the informational density of the sentence, which can result in cognitive overload and engender comprehension failure. In an essay titled "The magic number seven, plus or minus two: Some limits on our capacity for processing information," prominent cognitive scientist George Miller (1969) posited that the "magical number seven" is the approximate number of items (e.g., simple facts, numbers, words) that we humans can hold in our short-term working memory at one time before they fade into oblivion. This means that, cognitively speaking, lengthy subjects and/or objects are likely to overwhelm students, disrupting their reading fluency and putting constraints on their comprehension processing. In Extract 45, for example, by the time students wade through to the main verb of the sentence, "*are banned*," they probably have forgotten what the 16-word subject is about. In fact, poor readers tend to erroneously recall "*inhabitants are banned*" as the main idea of the sentence. In Extract 48, the verb (*is*) is flanked with two lengthy noun phrases that contain multiple pre-modifiers and post-modifiers.

45. *Military activities, hunting, mining, and other actions that might harm the environment and its wild inhabitants* are banned.
46. A chemical reaction is *a process that produces one or more substances that are different from the original substances.*
47. *Other rocks with no visible grain* are made up of *extremely small particles of silica that settle out of water.*
48. *The most important climax community in the equatorial regions of the world* is *the lush, green plant growth of the tropical rain forest.*

Complex Sentences

In the ordinary language of everyday social interaction, clauses are typically chained together through coordinating conjunctions (e.g., *and, and then*) or merely juxtaposed (e.g., use of direct quote), each contributing independently to the spoken discourse structure. In scientific language, clauses are typically linked through logical dependency relationship, resulting in hierarchically complex syntactic structure (Schleppegrell, 2004). Complex sentences are sentences with multiple dependent clauses. Dependent clauses include those introduced by subordinating conjunctions (e.g., *when, as if, because*), as well as those projected through verbs of saying and thinking (e.g., *He reported/thought that the meeting had been canceled*). These clauses are called subordinate clauses. Some dependent clauses are embedded within another clause; these are called embedded clauses. When a sentence contains multiple subordinate clauses, as in Extracts 49 and 50, or multiple embedded clauses, as in Extracts 51 and 52, the logical links and dependency relationship within the sentence take time to sort through. In Extract 49, three different logical links are encoded through the use of contrastive (*while*), causal (*because*), and comparative (*as*) conjunctions. In Extract 52, two different relative pronouns (*where*, *that*) introduce two embedded clauses to modify the same noun "*the place*." A third embedded clause with the relative pronoun (*that*) omitted is used to modify "*the things*" in the second embedded clause, which is introduced by "*that*" as well.

49. Stars shine with their own light, *while* Venus shines *because* it is reflecting light from the sun, just *as* the other planets and moons do.
50. Stars in a constellation can look *as if* they are close together, *even though* they are at very different distances from Earth.
51. The Epstein-Barr virus, for example, was named for the two scientists *who* first identified the virus *that* causes the disease *known* as infectious mononucleosis.
52. An organism's habitat is the place *where* it lives and *that* provides the things [*THAT*] it needs to survive.

When a sentence contains both subordinating and embedded clauses, as in Extracts 53 and 54, it can be especially taxing on comprehension, because readers will need considerable time to sort through the multiple logical links and dependency relationships established in the sentence. An overemphasis on reading speed and decoding accuracy, as is the case in some fluency-oriented reading instruction, can unfortunately undermine such an effort. In Extract 54, for instance, the first "*that*" introduces a subordinate clause, whereas the second and third "*that*" introduce two embedded clauses used to modify "*plants or animals*" and "*conditions*," respectively. Syntactic deconstruction of this sort can illuminate/clarify relationships among the different parts of a sentence and help poor readers untangle what appears to be a "language mess."

53. The amount of space *in which* a plant grows determines *whether* the plant can obtain the sunlight, water, and soil nutrients [THAT] it needs.
54. Darwin reasoned *that* plants or animals *that* arrived on one of the Galapagos Islands faced conditions *that* were different from those on the mainland.

Interruption Construction

Another fairly common feature of scientific English is the use of grammatical structures to delay the completion of a basic clause pattern. Perera (1984) called these structures "interruption constructions," so called because they interrupt the normal clause structure in order to highlight a particular word or phrase in the sentence. Because of their placement, interruption constructions, especially the lengthy ones, can disrupt the flow of reading and contribute to comprehension glitches. For example, in Extract 55, the phrase "*many too small to be seen without a hand lens*" delays the completion of the sentence by separating the subject (*hundreds of pores*) from its verb (*dot*). This gives prominence to the subject, but at the same time disrupts the reading flow. In everyday language, it is more common for the verb to follow the subject immediately. This explains why students may find it easier to read and comprehend everyday sentences like these without interruption constructions: "*Hundreds of pores dot a sponge's body. Many of these pores are too small to be seen without a hand lens.*"

Similarly in Extract 56, the interruption construction, in this case an adverbial clause, further distances the already lengthy subject—"*The belief that all parts of the environment are equally important*"—which is itself an embedded clause, from the main verb of the sentence (*is*). In Extracts 57 and 58, the interruption constructions (italicized), coupled with the use of multiple commas (,), have the potential to disrupt reading flow and cause confusion. In Extract 57, two interruption constructions, "*such as wheat, rye, oats, barley, and corn*" and "*which serve as staple foods for humans,*" separate the subject (*cereal grains*) from its verb (*are*). In Extract 58, "*including corn, wheat, and rice*" and "*such as lilies and tulips*" not only separate the subject (*grasses and plants*) from its verb (*are*), but the two constituents of the subject from each other.

55. Hundreds of pores, *many too small to be seen without a hand lens,* dot a sponge's body.
56. The belief that all parts of the environment are equally important, *no matter how useful they are to humans,* is the preservation viewpoint.
57. Cereal grains *such as wheat, rye, oats, barley, and corn, which serve as staple foods for humans,* are types of grasses.
58. Grasses, *including corn, wheat, and rice,* and plants *such as lilies and tulips* are monocots.

Passive Voice

In scientific English, there is a tendency to avoid active voice in favor of passive voice. One reason passive voice is privileged is that it is a useful and sometimes necessary textual organization strategy. For example, the use of passive voice in Extract 59 enables the writer to pack more information after the verb "*form,*" thereby achieving the syntactic effect of "end focus" (Perera, 1984). It would have been not only awkward, but confusing to say "*Sediments deposited by the Mississippi River as it entered the Gulf of Mexico formed much of this plain.*"

59. Much of this plain [Gulf Coastal Plain] was formed from sediments deposited by the Mississippi River as it entered the Gulf of Mexico.

Another reason for the use of passive voice is that it enables the author to achieve some degree of objectivity and authority by not mentioning the human/animal actors involved in the scientific process. In Extract 60, for instance, instead of saying "*Scientists think that photosynthesis and respiration are opposite processes,*" the actor who does the thinking is buried through the use of passive voice. While this avoidance of human/animal agency can create the effect of an invisible expert presenting objective information, at the same time it also makes the text less involving and more alienating. One reason that students often prefer narrative versions of science, such as informational storybooks, is that these trade books have specific human or animal characters that can evoke personal involvement and emotional responses.

The other consequence of using passive voice is that the writer can avoid naming the human actor, companies, or institutions responsible for certain acts. For example, in Extract 61, the passive voice construction "*were cut down*" enables the textbook writers to bury the human agency responsible for deforestation and thus higher firewood price. Should the sentence be reworded in active voice, an actor will have to be inserted to serve as the grammatical subject for the sentence: *As [logging companies] cut down forests, firewood became more expensive.* The insertion of grammatical subject would have directly implicated the party responsible for making firewood expensive, which can make textbook companies and/or authors liable for lawsuits. Likewise, in Extracts 62 and 63, passive voice allows the author to not name the party responsible for doing careful excavation work and for reducing earthquake damage. Taken together, these examples suggest that passive voice can be a useful grammatical resource for obscuring responsibility and agency. Those who do not understand the role passive voice plays in construing values and ideology are less likely to become critical readers and aware of the environmental and ecological issues implicated in the text.

60. Photosynthesis and respiration can *be thought of* as opposite processes.
61. As forests *were cut down*, firewood became more expensive.
62. Excavations to unearth bones or other evidence of past life are often slow processes that involve a lot of careful work. Care must be taken so that the remains *are not broken or destroyed* as they *are removed* from the soil.
63. To reduce earthquake damage, new buildings must *be made* stronger and more flexible. Older buildings must *be modified* to withstand stronger quakes.

Summary

I have identified close to a dozen specific linguistic features that occur with regularity in middle-school science textbooks. While some of these features may be found in other academic subject texts (e.g., Fang, Schleppegrell, & Cox, 2003) and even in adults' everyday language as a mark of prestige and power, they seem particularly concentrated in school science, creating in effect a syndrome that can be characterized and recognized as "the language of school science." As Tables 2 and 3 demonstrate, multiple linguistic features are often simultaneously at work in science texts, be they brief (see Extract 64) or extended (see Extract 65). Together, these features render science texts more turgid, dense, abstract, and distilled than the materials that children have been used to reading during the early years of schooling. Often taken for granted by proficient adult readers, these features can and do present significant comprehension challenges to adolescent students, especially struggling readers and English-language learners, who do not have sufficient experience with

Table 2. Linguistic features in Extract 64

Linguistic features	Examples
Technical vocabulary	absorb, withstand, drought
Ordinary words with non-vernacular meanings	spells
Ellipsis	... and [THAT] can withstand ...
Lengthy noun phrase	extensive root systems, called sod, that absorb water
Complex sentence	... *that* absorb water ... *when* it rains ...

academic texts in content areas such as science. Knowing what these features are and understanding how they work to construct scientific knowledge, principles, and ideology is an essential part of science literacy. As Yore et al. (2004) have argued, "Language is an essential technology and thus an integral part of science and science literacy, particularly written language" (p. 348).

64. Grass plants have extensive root systems, called sod, that absorb water when it rains and can withstand drought during long dry spells.
65. The largest structure in the cytoplasm of a eukaryotic cell is the nucleus. The nucleus directs all the activities of the cell. The nucleus, shown in Figure 14-11, is like a manager who directs everyday businesses for a company and passes on information to employees. A nucleus is separated from the cytoplasm by a nuclear membrane. Materials enter and leave the nucleus through openings in the membrane. The nucleus contains the instructions that direct all of the cell's functions. These instructions are found on long threadlike chromatin. Chromatin is

Table 3. Linguistic features in Extract 65

Linguistic features	Examples
Technical vocabulary	cytoplasm, eukaryotic cell, nucleus, membrane, chromatin
Ellipsis	* ... for a company and [WHO] passes on ... * A structure [THAT IS] called a nucleolus ...
Relative pronoun	... the form of chromosomes, *which* are easier to see
Abstract nouns	openings, instructions
Lengthy nouns	* the largest structure in the cytoplasm of a eukaryotic cell * a manager who directs everyday businesses for a company and passes on information to employees * the chemical that is the blueprint for the cell's structure and activities
Complex sentences	* *When* a cell begins to divide, the chromatin tightly coils *and* takes on the form of chromosomes, *which* are easier to see
Interruption constructions	* The nucleus..., *shown in Figure 14-11*, is like a manager ...
Passive voice	* ... *are found* on long threadlike chromatin * .... *is* also *found* in the nucleus

a form of hereditary material. It is made of proteins and DNA. DNA is the chemical that is the blueprint for the cell's structure and activities. When a cell begins to divide, the chromatin tightly coils and takes on the form of chromosomes, which are easier to see. A structure called a nucleolus is also found in the nucleus.

Strategies for Promoting Students' Understanding and Use of LSS

The foregoing section shows that written school science adopts a wide range of linguistic features that are seldom used in everyday informal spoken interaction and that students often find peculiar and alienating. The differences between LLS and EL are constitutive of the broader and significant differences that exist between everyday life and the domain of science (see Reif & Larkin, 1991). In part because of these differences, the cognitive means (e.g., implicit learning) that are effective in acquiring everyday commonsense knowledge are often inadequate in attaining the specialist knowledge of science. Thus, a more "visible pedagogy" (Bernstein, 2000), whereby students' attention is consciously drawn to salient features of LSS, will also be needed in students' learning of school science. Without an explicit awareness of the distinctive differences, as well as similarities, between LSS and EL, students are likely to experience learning difficulties in science. In fact, as Wellington and Osborne (2001) have pointed out, for many students the greatest barrier to learning science lies in learning its language. Because middle-school students often have misconceptions about science reading, science text, and science reading strategies (Craig & Yore, 1995), it is critically important that teachers design pedagogical tasks that aim at raising students' awareness of the unique features of LSS. Explicit analysis of the linguistic basis of scientific meaning-making can help students better understand how language construes particular ways of thinking/reasoning in science and broaden their participation in the many contexts of science learning (Schleppegrell, 2004). According to Veel and Coffin:

> There is now considerable evidence as to the viability and successful outcomes of explicit teaching about the specialized language of schooling [such as LSS]. This includes substantial anecdotal evidence from teachers and students as well as more empirically based work by researchers and evaluators. (1996, p. 225)

In the remainder of this section, I describe several specific strategies for unpacking and displaying "the organization and logic of scientific ways of using language" (Lemke, 2001, p. v) to help teachers better promote students' understanding and use of scientific language. Because of their theoretical grounding in functional linguistics (Halliday & Matthiessen, 2004; Schleppegrell, 2004), these strategies differ from the traditional, rule-based grammar instruction and have the potential to develop linguistic insights among students that can facilitate their transaction, as well as engagement, with text. They have been used with some success in inquiry-based middle-school science classrooms that infused reading instruction (Fang et al., 2005). This focus on the language of school science should not be interpreted as devaluing the basic reading skills (e.g., decoding), schema building activities (e.g., anticipation guide, KWL), or cognitive/metacognitive strategies (e.g., predicting, inferencing, visualizing, think-pair-share) that students have learned or been exposed to during the elementary grades and are continuing to consolidate in middle school. Rather, these reading skills and strategies continue to play an important role in understanding texts in science and other content areas; however, they alone are often insufficient to ensure successful comprehension of content area texts at the secondary level, because of the unique linguistic challenges these texts present.

Vocabulary Building

One of the greatest challenges in learning science is to learn its specialized vocabulary. The classification system that scientists use today is based on the contributions of both Greek scholar Aristotle and Swedish scientist Carolus Linnaeus, who used Latin words in his naming system. This means that technical terms in science often have Greek or Latin origins. As such, they are typically multi-morphemic. Direct instruction of roots and affixes can, therefore, help students develop control over the technical vocabulary of science and hence more precise understanding of science. Some of the more common prefixes, suffixes, and roots in middle-school science are presented in Table 4. The list was compiled based primarily on my own examination of the bolded words in the two science textbooks mentioned earlier.

These morphemes can be introduced incrementally and judiciously as they appear in key words that are part of a particular unit of study. They can be taught in conjunction with other aspects of vocabulary studies (e.g., scientific meaning vs everyday meaning, semantically-related words vs orthographically-similar words, synonyms, antonyms) through clear explanation, modeling, guided practices, and meaningful applications. For example, in a sixth-grade unit on waves, a team of university-based reading educators and school-based science teachers developed a word chart (Figure 1) to help students understand and differentiate the key terms related to types of waves (*mechanical, electromagnetic, transverse, compressional, longitudinal*), properties of waves (*amplitude, wavelength, frequency, trough, crest*), and behavior of waves (*reflection, refraction, diffraction, interference*) (Fang et al., 2005). This chart can be completed as a group and/or individual activity after the reading of text or at the conclusion of the unit to help students review key concepts related to waves.

Noun Expansion

One of the features of scientific writing is the use of lengthy noun phrases. Analysis of the structure of these extended noun phrases can thus further students' understanding of how information is typically packed and expanded in the language of science (Unsworth, 1997). A lengthy noun phrase in science consists of pre-modifiers and/or post-modifiers. Pre-modifiers can include pointers (e.g., *these, that*), numeratives (e.g., *first, five*), and describers (e.g., *hungry, very ferocious*). Post-modifiers can be prepositional phrases (e.g., *with sharp teeth*) and/or embedded clauses (e.g., ... *that attacked the dog*). Students can engage in what many teachers

Table 4. Common prefixes, roots and suffixes in middle-school science

Prefix	**a-/ab-** (away, not), **ad-** (forward), **aero-** (air), **amphi-** (both), **ante-** (before), **anti-** (against, opposite), **archae-** (ancient, primitive, chief), **arthro-** (jointed), **audio-** (hearing, sound), **auto-** (self), **bi-** (two), **bio** (life), **cardio-** (heart), **chemo-** (chemical), **chloro-** (green), **chroma-** (color), **circum-** (around, circle), **centi-** (one hundredth), **co-/col-/com-/con-** (together), **contra-** (opposed), **de-** (down), **di-** (two), **dia-** (across, through), **dis-** (not, away, apart), **dys-** (bad, difficult), **eco-** (environment), **ecto-/exo-/ extra-** (outside), **electro-** (electricity), **en-** (in, to cause), **equi-** (equal, same), **ex-** (out, intensive), **geo-** (earth), **heter-** (different), **homo-** (same), **horti-** (garden), **hydro-** (water), **hyper-** (over), **hypo-** (below normal), **idio-** (individual), **infra-** (beneath, inferior to), **inter-** (between), **intra-/intro-** (within), **iso-** (equal, uniform), **mal-** (bad, abnormal), **meta-** (change, next), **meter/metr-** (measure), **meso-** (middle), **micro-** (small, one millionth), **milli-** (one thousandth), **mono-** (single), **morph-** (form, shape), **multi-** (many), **noct-** (night), **non** (not)-, **ob-/oc-/of-/op-** (toward, against), **omni-** (all), **ped-** (foot), **per-** (throughout), **peri-** (around), **photo-** (light), **phono-** (sound), **poly-** (more than one), **pre-** (before), **primi-** (first), **pro-** (in favor of, before), **proto-** (earliest), **post-** (after, behind), **quadri-** (four), **semi-** (half), **re-** (back, again), **rhodo** (red), **semi-** (half), **spher-** (round), **strato-** (horizontal layer), **sub-** (under), **super-** (over), **supra-** (beyond), **tele-** (distant), **thermo-** (heat), **thigma-** (touch), **trans-** (across), **tri-** (three), **ultra-** (above, beyond), **un-** (not), **uni-** (one)
Root	**bene** (well), **caten** (bind), **cred** (to believe), **derm** (skin), **dict** (to say), **duc** (to lead), **fac/fact** (to make), **fer** (to carry), **flect/flex** (to bend), **flu** (to flow), **form** (to shape), **fract** (to break), **ject** (to throw), **med** (middle), **mis/mit** (to send), **pend** (to hang), **port** (to carry), **pos/pon** (to place), **press** (to press), **rupt** (to break), **scrib/script** (to write), **sect** (to cut), **spect/spic** (to look), **spir** (to breathe), **struct** (to build), **tend** (to stretch), **tract** (to pull or draw), **ven/vent** (to come), **vers/vert** (to turn), **vid/vis** (to see)
Suffix	**-able/-ible** (capable/worthy of, inclined to be), **-al** (action, relating to, characterized by), **-ance/-ence** (state/condition/action), **-ant/-ent** (performing/promoting/causing a specified action), **-ary** (pertaining to), **-ate** (having, characterized by, to act upon in a specified manner), **-cide** (killing), **-cy** (condition, action), **-cyte** (cell), **-dom** (state, domain), **-emia** (blood), **-er/-or** (one that is or performs a specified action), **-ful** (full of), **-ian** (relating to, resembling, an expert of), **-ic** (of, pertaining to, characterized by), **-ion** (process, condition), **-ism** (action, characteristic behavior/quality, doctrine), **-itis** (disease of), **-ity** (condition, quality), **-ive** (performing or tending toward a specified action), **–ium** (chemical element or group), **-ize** (cause to be or become), **-less** (without), **-ly** (in the manner of), **-ment** (action, process, means), **-ness** (quality, condition), **ology** (a branch of learning), **-osis** (condition, disease), **-ous** (full of, characterized by), **pod** (foot), **-th** (process, state, quality), **-tion/-sion** (action, process), **-tious** (characterized by), **-ude** (state, quality), **-ular** (of, relating to, resembling), **-ward** (in the direction of), **-y** (characterized by, consisting of, tending toward, somewhat, group)

Note: Some of the prefixes and suffixes are Greek-combining forms.

would call "elaboration" exercises, which require expansion of simple nouns (e.g., *crocodiles*) into lengthy noun phrases with pre-modifiers and/or post-modifiers (e.g., *those two very ferocious crocodiles with sharp teeth that attacked the dog*). Teachers can start out by having students add one or two modifiers to a simple noun and gradually increase the number of modifiers as students gain more comfort with the task.

Word Chart

Student Name ____________________ Date ____________________

Unit of Study ____

My word is ____

I recognize the meaning of this part of the word ____________________
(identify any prefix, root, or suffix in the word that you know)

This word reminds me of ________________________________
(identify a semantically-related or orthographically-similar word, as well as a real life scenario triggered by the word)

In science, this word means ____________________________
(write down a textbook/dictionary definition or your own paraphrase of the definition)

A sentence in which this word is used ____________________
(from text or your own)

This word is part of our unit because it fits into this category of waves ________
(type, property, or behavior)

Other words in this category include ____________________

Figure 1. Word chart

noun:	**crocodiles**
add pointer:	those crocodiles
add number:	those two crocodiles
add describer:	those two very ferocious crocodiles
add 1 postmodifier:	those two very ferocious crocodiles with sharp teeth
add 2 postmodifiers:	those two very ferocious crocodiles with sharp teeth that attacked the dog

Figure 2. Noun expansion chart

A related activity is to have students identify noun phrases in the texts they read/ write and list them from simple to the most complex. By comparing the kinds of nouns (e.g., simple vs lengthy) used in the texts they read and in their own writing, students will gain a deeper understanding of and appreciation for the ways nouns are typically employed by experts in presentation of information and construal of knowledge. This should, in turn, help them become better readers and writers of science. Table 5 displays two texts, one a science report on the differences between alligators and crocodiles written by a seventh-grade student and the other a supplemental reading passage used by the student's science teacher to teach the differences between alligators and crocodiles. A comparison of the nouns (underlined) in the two texts shows that the 13-year-old student uses significantly fewer nouns with pre-modifiers and/or post-modifiers (22%) than does the sample reading passage (60%), an indication of her possible lack of sufficient familiarity with scientific language. Another striking difference between the two texts is that whereas the sample reading

Table 5. Comparison of nouns in sample reading passage and student writing

	Sample reading passage	Student writing
Text	Alligators and crocodiles are related and make up a group of water-loving animals called crocodilians. Like other reptiles, alligators and crocodiles have scaly skin and lay eggs with shells. They are cold-blooded and can often be seen laying in the sun to stay warm. Their webbed feet and streamlined bodies are perfectly adapted for spending much of their lives in water. Though crocodilians seem awkward on land, they can move with surprising speed when needed. Crocodiles and alligators are alike in many ways, but they also have differences. The crocodile's skull and jaw are narrower than an alligator's. When its jaws are shut, it has more teeth sticking out than an alligator does. Another difference is their choice of habitat. Alligators live in fresh water while more crocodiles live in salt water.	Have you ever wondered what makes an alligator so cool? Well, they are reptiles, they are actually not the same as crocodiles and they are carnivores. The cool thing about being a reptile is because they are so much different than other animals. That is cool. They are different than crocodiles. Crocodiles have pointed snouts and are smaller. Alligators have round snouts and are bigger. Alligators are carnivores. They eat meat like fish, dogs, chickens and have killed humans. They are scary. I know they are scary but still they are amazing creatures. I think they are really cool.
Noun use	total number of nouns: 30	total number of nouns: 31
	% of simple nouns: 40%	% of simple nouns: 78%
	% of nouns with only pre-modifiers: 40%	% of nouns with only pre-modifiers: 13%
	% of nouns with only post-modifiers: 10%	% of nouns with only post-modifiers: 3%
	% of nouns with both pre-mosifiers and post-modifiers: 10%	% of nouns with both pre-mosifiers and post-modifiers: 6%

Note. Misspellings in the student text have been corrected for ease of comparison. Simple nouns include pronouns as well as nouns without any pre-modifiers or post-modifiers, except indefinite articles.

passage uses several abstract nouns (e.g., *another difference*, *their choice of habitat*), the student text uses none. The use of abstract nouns, or, more specifically, nominalized phrases, is an important marker of developing advanced literacy (Christie, 2001).

Sentence Completion

Sentence completion works like cloze. It requires students to synthesize information in prior text into a noun (or noun phrase) that can then become the subject of the next sentence. Teachers can identify passages in science texts that contain nominalized phrases, such as Extracts 66–70, and leave the nominalized phrases blank for students to complete. Sentence completion tasks can help students see how nominalization allows the text writer to take a wide range of grammatical and semantic data that have been previously presented in the text, and then express them or refer to them for further discussion. They allow students to gain insights into the development of cohesive texts with discursive flow. They also make students better able to figure out the meaning of abstract/technical terms that are derived from the grammatical process of nominalization.

66. As an infant, much of your skeleton was cartilage. Over time, most of the cartilage has been replaced with hard bone tissue.________________________ usually is complete by the time you stop growing. (Sample key: the replacement of cartilage by bone tissue)
67. Some of these rocks have no crystal grains because when they form, they cool very quickly.____________gives these rocks the smooth, shiny texture of a thick piece of glass. (Sample key: this quick cooling)
68. After seeds have formed, they are usually scattered, sometimes far from where they were produced.__________is called seed dispersal. (Answer: the scattering of seeds)
69. The cells that line the nasal cavities have cilia, tiny hairlike extensions that can move together like whips.____________________ sweeps the mucus into the throat, where you swallow it. (Sample key: the whip-like motion of these cilia)
70. Strands of glass fiber are woven together and strengthened with a liquid plastic that sets like glue.__________makes a strong, hard solid that may be molded around a form to give it shape. (Sample key: the combination)

Paraphrasing

Another strategy is to have students translate back and forth between LSS and EL. Such paraphrasing exercises will increase students' ability to handle the specialized language of science, for, ultimately, it is through their everyday language and experience that students develop new meanings and generate new knowledge. According to Lemke:

> The problem of learning through [science] texts is...fundamentally a problem of translating the patterns of written language into those of spoken language. Spoken language

is the medium through which we reason ourselves and talk our way through problems to answer. It is, for the most part, the medium in which we understand and comprehend. (1989, p. 136)

For example, students can practice translating the more ordinary language (e.g., *Alligators and crocodiles are also different in how they pick their places to live*) into scientific language (*Another difference between alligators and crocodiles is their choice of habitat*). Conversely, scientific language (e.g., *The belief that all parts of the environment are equally important, no matter how useful they are to humans, is the preservation viewpoint*) can be paraphrased into everyday language (*Some people believe in preserving the environment, because they think that all parts of the environment are equally important, no matter how useful they are to humans*). In doing these exercises, however, it is important for teachers to point out the similarities and differences between LSS and EL, highlighting aspects of daily life that cannot be readily refined as well as those in the science domain that are not readily translatable into everyday language, so as to "avoid simplistic transfers of ways of thinking from everyday life into science, or vice versa" (Reif & Larkin, 1991, p. 756).

These exercises can help bridge the gap between the seemingly exoteric LSS and the commonsensical language that students use in everyday life. By moving back and forth between the familiar and the alien patterns of language, students will gain a deeper appreciation of the similarities and differences between the domains of science and everyday life, particularly as they relate to the language used to construe each domain. Such understanding is critical to students' learning of the peculiar forms and functions of scientific language and to their development of communicative competence in science.

Sentence Stripping

Unlike the chaining syntax of EL, where clauses are linked together primarily through coordination, scientific language employs complex sentences with hierarchical structure using both subordinate and embedded clauses. Students need help sorting through the complex clause structure of these sentences. This can be done through analyzing, with students, the different ways in which clauses are combined to form complex sentences in science. In Extract 71, for example, the first sentence establishes a conditional relationship between the main clause and the subordinate clause through the use of "*as long as*." Within the main clause itself, an embedded clause, introduced by a relative pronoun (*that*), elaborates on the noun (*a pipe*). In the second sentence, the main clause is again linked with the subordinate clause with a conditional conjunction (*when*). An interruption construction (*like the flow ... the ground*) delays the completion of the main clause. Within this interruption construction, an embedded clause introduced by a relative pronoun (*that*) serves to provide more information on the noun (*the wire*). Discursive anatomy of this sort has the potential to ease struggling readers' comprehension difficulty by helping them untangle what appears to be a syntactic "mess".

71. Water will flow in a pipe *that* connects the reservoirs only *as long as* a difference in water level exists. The flow of water in the pipe, like the flow of charge in the wire *that* connects the Van de Graaff generator to the ground, will cease *when* the pressures at each end are equal. (Hewitt, 1998, p. 399)

Developing Awareness of Signposts

Science is a discipline that relies on not only practical experience with the natural world, but logic of argument (Yore et al., 2004). Scientists are trained to be both accurate and precise in conducting scientific activities; they are cautious about their use of language in terms of not only facts, but logic as well. In conceptualizing science as argument, Kuhn (1993) asserted that the development of scientific thinking is closely linked to the ability to think argumentatively. Scientists need to make coherent and organized arguments in order to convince the scientific community of their theories and to avoid inconsistencies and contradictions. In constructing such rhetorical arguments, they use a varied set of connectives with restricted, precise meanings. This is contrary to EL, where a few conjunctions (e.g., *and, and then, but, so, because, if*) are used pervasively and often in vague and imprecise ways (Schleppegrell, 2004). Thus, to truly understand and appreciate scientific arguments, students need to gain control over the logical–semantic resources, such as connectives, that scientists use to construct such arguments. Table 6 identifies some of the more commonly used connectives and their meanings in science. These connectives are instrumental in explicating the logical–semantic relationship among sentences and among paragraphs. However, they can be taken for granted or misunderstood, as demonstrated earlier. To understand the logic of science, it is imperative that students pay attention to the connectives that can cue them to what has been said earlier in the text and what is to come next. The italicized words/phrases in Extracts 72–74 are such cues. Developing awareness of these signposts can enhance students' understanding of the linkages among ideas and facilitate construction of a coherent mental representation of text.

72. *As* forests grow, they take in carbon dioxide. *If* an entire forest is cut down, it doesn't take in carbon dioxide, *and* more of this gas is left in the atmosphere.
73. Serious earthquakes are east of the Rockies. *Nonetheless*, the region has experienced some of the most powerful quakes in the nation's history.
74. Some consumers eat both plants and animals. *For example*, the kinkajou on the next page eats fruits as well as ants and termites. *Because* kinkajous are consumers that eat both plants and animals, scientists call them omnivores.

Language, Reading, and Science Literacy

Middle-school students are often characterized as apathetic readers who feel alienated from academic subjects like science (Lemke, 2001; Ley, Shaer, & Dismukes, 1994). To help address this problem, two approaches have been proposed in recent

Table 6. Common connectives used in middle-school science

Types of connectives	Meaning	Examples
Additive	To provide additional information about a topic	and, in addition to, moreover, furthermore, also, nor
Adversative/contrastive	To provide contradictory information	but, on the other hand, yet, however, conversely, whereas
Appositive	To elaborate on previously stated information	that is, in other words, for instance, for example, to illustrate
Causal	To offer reason or explanation	therefore, hence, as a result, for this reason, because
Comparative	To compare and contrast	likewise, unlike, similarly, in contrast, as
Concessive	To acknowledge a concession	yet, still, nevertheless, while, though, despite that
Conditional	To state circumstances under which something occurs	otherwise, when, if, then
Spatio-temporal	To provide spatial and temporal links	finally, previously, next, secondly, lastly, meanwhile, as, while, when
Summative	To summarize previously stated information	in short, in conclusion, to sum up, or else, apart from that
Variative	To offer an alternative	instead, alternatively

Note. Adapted from Halliday and Matthiessen (2004, pp. 82, 541).

years and are fast becoming popular. One is to minimize (or even eliminate) texts from science instruction in favor of an inquiry-oriented, hands-on curriculum that focuses on experiments and observation. The other is to replace science textbooks with educational novels that present scientific information in a storybook format. Both proposals have merits in that they have the potential to motivate learners, stimulate their engagement, and scaffold their learning of science. However, as critical as hands-on activities are to science learning, they alone are insufficient to ensure the development of truly "scientifically literate persons" (Rutherford & Ahlgren, 1990). According to Halliday (1998), science is "one and the same time both material and semiotic practices" (p. 228). A vital part of being a scientist and a key element of scientific literacy is the capability and habit of "reading carefully, critically and with a healthy scepticism" (Wellington & Osborne, 2001, p. 42). Students need to be able to read and write in the language of science in order to effectively communicate in science. Furthermore, as Norris and Phillips (2003) have argued, the development of modern western science is dependent on written science texts and without exposure to these texts, students are severely limited in the depth and breadth of their learning of scientific knowledge, principles, and values.

Relative to the second proposal, it is true that educational novels such as informational storybooks use structure and language that are more familiar and less alienating to students. Judicious use of such books can thus be beneficial in that they can pique students' interest and scaffold their learning from more prototypic expository texts in science. However, it must be cautioned that excessive use of storybooks for purposes of science learning and teaching runs the risk of underexposing students to scientific language. Scholars (e.g., Halliday & Martin, 1993) have argued that scientific meanings often cannot be expressed in the ordinary language of everyday storytelling; instead, science has evolved to have its own language, which is functional for construing scientific concepts, knowledge, and worldview. Reif and Larkin noted:

> [S]cientific advances over the several centuries have led to scientific knowledge that has become increasingly more voluminous, more precise, more abstract and highly symbolic, and more prone to deal with phenomena and concepts never encountered in everyday life ... As a result, the gap between scientific knowledge and that of everyday life has become increasingly large. (1991, p. 740)

This suggests that students need experience with the authentic, not "diluted," language that scientists use to communicate their knowledge and understanding of the natural and social worlds. Exposure to the language of school science constitutes an essential part of such an experience.

Exposure alone cannot guarantee mastery, however. Explicit attention to the specialized language of science is needed, for, as Wellington and Osborne (2001) have suggested, without a conscious understanding of the peculiar grammar of science, science will remain a foreign language to many students. Along the same vein, Gee proposed:

> [S]tudents need to have "reading lessons" ..., during which people more expert than the students model how they read such [science] texts and engage the students in overt discussion about the language and genre conventions of such texts and how these conventions arise from history and relate to current practices. (2004, p. 31)

Although the discourse of science is often viewed as a language of hierarchy that privileges the expert (Luke, 1996), it is undeniable that without control over this meaning-making resource, students will have limited access to a specialized yet powerful domain of cultural experience and be further disadvantaged in a class-stratified society that has become increasingly reliant on science and technology (Martin, 1998).

Unfortunately, current reading comprehension instruction at the secondary level focuses almost exclusively on two narrow, highly popularized sets of strategies: fluency-oriented strategies, such as repeated reading, chunking, and prosody monitoring (e.g., Hudson, Lane, & Pullen, 2005; Rasinski, 2003); and cognitive and metacognitive strategies, such as predicting, inferencing, making connections, visualizing, and think-aloud (e.g., Harvey & Goudvis, 1999; Topping & McManus, 2002; Tovani, 2000; Wilhelm, 2001). These strategies are certainly important to the development of fluent, engaged, and reflective readers. However, they alone are often inadequate to ensure successful comprehension of content area texts at the secondary level. For example, as demonstrated earlier, dysfluent reading of science texts can be a manifestation of students' lack of familiarity with the specialized language of science. This suggests that fluency instruction will be more productive if it targets the root of the problem by helping students develop linguistic insights into LSS, one variety of academic language that does not sound as intuitive to students as everyday language. As students gain familiarity with and insights into the structure and logic of LSS, they will begin to make more sense of and, consequently, become more engaged in the instructional practices aimed at improving their reading speed, phrasing, and prosody. Furthermore, the cognitive and metacognitive skills/strategies currently being emphasized in comprehension instruction (e.g., predicting, making connections, visualizing, inferencing) are the ones that students have typically acquired during childhood years (Hirsch, 2003) and seem to have no trouble using in their everyday lifeworld. This means that students generally do not lack these skills and strategies. Therefore, while some teaching of cognitive and metacognitive skills/strategies is helpful, excessive instruction in them can be a waste of time (Hirsch, 2003). It seems that comprehension instruction in science and other content areas should pay more attention to the barriers that prevent students from successfully applying the skills and strategies they already possess when reading academic subject texts. One such barrier is the unique language demands of curricular subject texts. Literacy pedagogy in science should, therefore, move beyond the narrow set of comprehension skills and strategies to include activities designed to raise students' consciousness about, as well as their ability to cope with, the specific linguistic challenges of science texts.

The language-based tasks described earlier exemplify some of the possible kinds of consciousness-raising activities that can be provided to promote students' understanding of and control over LSS and, ultimately, the professional language of science. These tasks do not have to be carried out as isolated worksheet practices. Rather, they should take place with connected texts in authentic reading and writing and as part of the reading/writing workshops in the context of "inquiry science" (National Research Council, 2000), using examples drawn from the texts that students read as well as from their own writing samples. Such exercises have the potential to achieve what has not been adequately accomplished with current secondary content area reading pedagogy. Specifically, they will allow students to better understand, appreciate, and, eventually, appropriate the grammatical choices that scientists typically make in the presentation of information, negotiation of role relationship, and structuring of text. Given the peculiar nature of scientific language and the developmental needs of students, explicit teaching should be carried out methodically and in a manner featuring a gradual release of responsibility (Unsworth, 2001). Specifically, there should be a great deal of teacher modeling at the beginning. As students gain experience and confidence, they can then engage in collaborative efforts, initially with teachers and subsequently with their peers, to solve the language puzzles of school science, before eventually moving to independent practices. By explicitly addressing the language demands of content area (e.g., science) reading, teachers can help break down the barriers between learner and text and will be in a better position to prepare motivated readers who can handle the language demands of advanced literacy competently and comfortably. Without such efforts, warned Reif and Larkin (1991), "students are likely to acquire merely superficial scientific knowledge—without an adequate understanding of its purpose and without much ability to use it effectively" (p. 757).

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