Unlocking Reading Comprehension With Key Science Inquiry Skills

by Roxanne Greitz Miller

As secondary science teachers, we appropriately focus the majority of our instruction on science content rather than the related subject areas, such as reading or writing, that support it. However, we must remember that scientific literacy cannot be attained without fundamental literacy—the ability to read and comprehend textual information and write competently about the subject under study (Norris and Phillips 2003). As a result, science teachers—schools' resident experts in digesting expository text laden with factual details, processes, and complex vocabulary—must "make it our business" to instruct students in the fundamental literacy skills that support scientific literacy, most importantly reading comprehension and writing composition in the expository domain. Fortunately for middle school science teachers, classrooms are a natural laboratory where the relationships between science, reading, and writing can be developed and strengthened to provide a foundation for students' learning and future career success.

The background

The reciprocal nature of science inquiry and reading is made explicit in the following definition of inquiry:

> *[Inquiry is] a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations* (NRC 1996).

More simply stated, one must be able to read and comprehend in order to examine science information, and must be able to compose (both in writing and orally) in order to communicate scientific results. On the lesser-known flip side, several research studies have shown the positive effects of science inquiry curriculum on developing students' reading skills and comprehension. On first review, teachers may wonder why this is so. While it is readily apparent

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that you can gain science knowledge through reading and that you must be able to read and write to “do” science, how do students gain reading skills *through* science? The basic answer may be found by examining what science is really meant to be. The Latin *scire*, from which the English *science* is derived, refers not to a subject area or academic domain, but rather “to knowing” about the world. Students who learn about their world by forming their own questions, comprehending information presented in varied forms, and expressing their knowledge both in writing and orally are better equipped to learn in any subject area. Additionally, four major cognitive strategies are used when effective readers read: (1) they plan, (2) they translate or interpret, (3) they reread, and (4) they reflect upon and evaluate what they read.

In order to promote the application of science inquiry skills to reading and writing, structured, scaffolded, and explicit instruction in their transference must occur within the classroom. Students who are high achievers or hail from educationally advantaged backgrounds intuitively apply inquiry strategies while reading. To meet the needs of all students, teachers must model and demonstrate inquiry thought during reading, building a toolkit of comprehension activities for students to use when reading in class and independently. These activities should use a common technical vocabulary to describe the similar thought processes between science and reading.

A framework

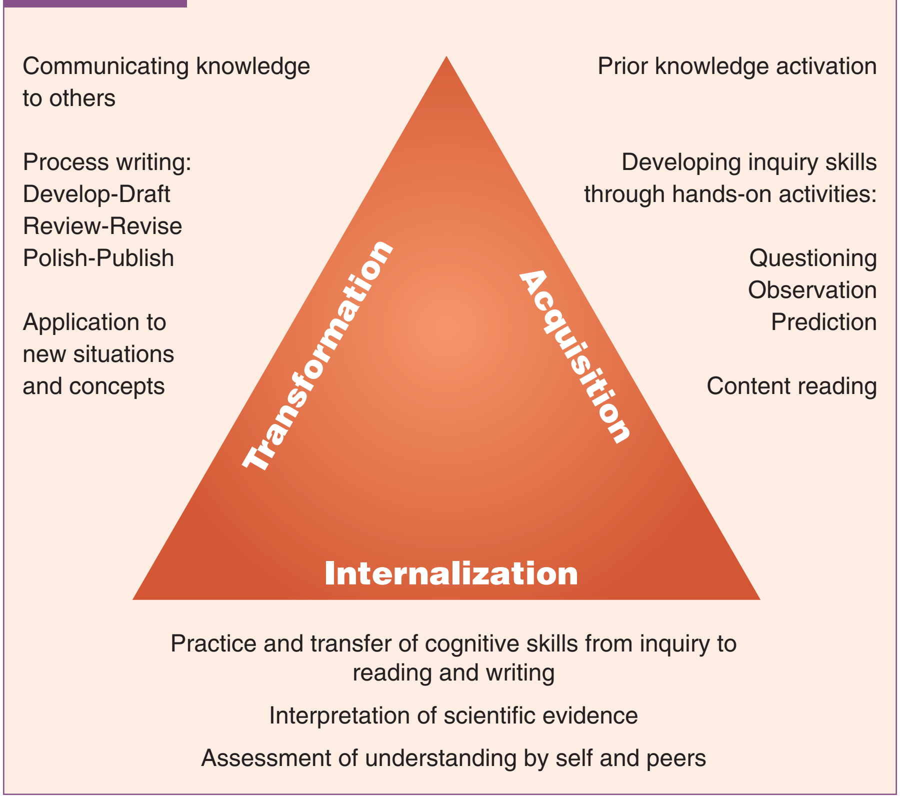
What do science teachers need to know in order to foster development and transfer of inquiry strategies from science to reading? Teachers do not need to know “everything” about science and reading to raise student achievement. Rather, they need to know a few things well: (a) which cognitive processes are shared in the building of scientific knowledge and the processes of reading comprehension, (b) how these processes can be transferred, and (c) how to promote deep learning through teaching.

I designed the Science-Cognition-Literacy (SCL) Framework (Figure 1) to give science teachers a basis for visualization of the sequencing of cognitive processes and instructional activities for developing science inquiry skills, and applying them to reading (and writing) activities based in science. The SCL Framework is intended to serve as a guide for putting all of the pieces together in a seamless fashion. Rather than treating reading and writing as ancillary activities to support science learning, in this model, the literacy activities are fully embedded into the science curriculum and take on an equally important role to those of hands-on inquiry experiences.

Within the SCL Framework’s cognitive phases of Acquisition, Internalization, and Transformation are embedded activities that address four essential elements in constructivist theories of learning: (1) connecting to prior student knowledge, (2) organizing new topical content, (3) providing opportunities for students’ strategic reflection, and (4) giving students opportunities to extend their learning. The effectiveness of this approach arises from cognitive scaffolding that assists students (and teachers) in organizing complex information and connecting it to prior schemata, and from templates that support social interactions around complex topics, interactions that Vygotsky (and others) see as critical to the development of reflective thought (Vygotsky 1978 and 1986).

The SCL Framework is best implemented during longer units of study that incorporate science inquiry investigations and reading/writing materials in a project-based format centering on one broad science topic, such as the states of matter. The longer

FIGURE 1 The Science–Cognition–Literacy (SCL) Framework



units allow for deeper refection on reading and sharing of student knowledge. However, the individual strategies from the Framework can be applied to stand-alone, single lessons that concentrate on a single reading sample and inquiry experience, and I would encourage you to do this as well. Shorter lessons built around a single reading sample with inquiry can serve as "steps" to building students' repertoires of reading skills and provide practice in using these inquiry strategies while reading, and also make apparent for students that these inquiry skills can be used during short reading assignments in other subjects, not only during longer science units.

The activities contained in the SCL Framework's Acquisition phase are aimed at developing student inquiry skills and science content knowledge to serve as connectors to the subsequent literacy activities. To begin this phase, teachers identify the particular science topic for the lesson (for example, phase changes within the states of matter). Teachers activate students' prior topic knowledge by leading them to actively reflect, share with others, and employ pre-writing and K-W-L (What I Know/What I Want to Know/What I Have Learned) as generative techniques for individuals and groups. Students write down and share their ideas about the topic, along with predictions and expectations about the upcoming activities. Collaborative sharing of prior knowledge serves not only to enrich students' topical comprehension, but also to assist the teacher in identifying the "knowledge level" of the class as a collective, along with preconceptions needing attention along the way. These written artifacts are used in later activities and stages to assist in designing the students' investigations, and as resources for students' self-assessments of their thinking.

Students then engage in hands-on science inquiry investigations related to the topic. Extended, reflective investigations are recommended by experts to promote the construction of more meaningful scientific concepts based upon the unique knowledge brought to the classroom by individual learners. The assumption is that when students interact with problems they perceive to be important and connected to their experiences, and when teachers are guided by what is known about learning, students are able to develop scientific concepts in dialogue with peer investigators. Placement of hands-on in-

FIGURE 2 **Key science inquiry skills and reading applications**

Science inquiry skill	SCL phase	Reading application to be taught to students
Prediction	Acquisition	Before reading, students should preview the text and predict what the reading sample is about from the title, illustrations, and other key text components. As students read, students should constantly predict and anticipate what the next points to be discussed in text will be.
Observation	Acquisition and Internalization	Students use their observation skills to take note of key points in text—headings, boldface terms, illustrations, special use of language. Students should use contextual clues from the reading to decode new vocabulary, observing where and how the new terms are used and what supporting vocabulary and ideas are used to extend their meaning.
Questioning	Acquisition and Internalization	The K-W-L technique can be used before, during, and after reading to generate questions related to student knowledge. As they read, students should make margin notes and use the think-aloud strategy to sketch questions on the reading sample (or extra paper) to provide a concrete reminder of points that were not understood and need to be discussed in small groups or with the teacher. During the reflection activities, students must constantly self-assess their understanding of the reading, questioning themselves and posing questions to others as appropriate.
Planning	Acquisition	When students preview the reading sample, they should examine the structure of the text (sequential, descriptive, compare/contrast, etc.) and select an appropriate graphic organizer or other organizing tool (such as a T-chart) to use while reading to organize the points of information in the text.
Reviewing, analyzing, and interpreting data	Internalization	After reading, students should review what they have read and revisit and revise their graphic organizers if necessary, reconstructing their ideas and incorporating their knowledge from the hands-on activities with what they have read.
Explaining and communicating	Transformation	Students should be required to explain, both orally and in writing, what they have read. Doing so strengthens reading comprehension and science content knowledge.

vestigations at the outset of the units provides students with concrete, first-person experience in applying cognitive inquiry skills that subsequently are tapped in later stages of the SCL Framework for transference to reading and writing.

If the SCL Framework is being applied to a unit, rather than a single lesson, then students read a variety of expository text sources for additional content information related to the science topic in parallel to the science investigation. Ideally, these texts will come from not only their textbooks, but also from tradebooks, magazines, and alternative media such as online text. Students should be taught to use the cognitive strategies of think-alouds, text analysis, graphic organizers, and contextual clues to grapple with unfamiliar reading vocabulary. Specific inquiry strategies and their application to reading are discussed in Figure 2.

After Acquisition, students move to the Internalization phase, focusing on two activities: practicing science-developed inquiry skills during reading and writing, and developing metacognitive thought about their learning. Sufficient time and opportunities for interaction and reflection are essential for meaningful learning in hands-on science activities; however, students often lack the time or opportunity for interaction with and reflection on central ideas because of time constraints of our regular school day. The Internalization phase aims to address this situation by placing an emphasis on, and deliberately planning time for, reflection and interactions between student groups and with the teacher after the hands-on activities.

In this phase, students critically reflect and share their thoughts on their investigations and reading activities during cross-talk activities, serving to further construct meaning and ameliorate educational differences among diverse students. Teachers facilitate these discussions, acting as inquiry "guides," drawing students' attention to the thinking processes used during inquiry, and explicitly modeling the manner in which inquiry skills acquired during science can be transferred and applied when reading. For example, teachers can explore with students the ways in which observation, questioning, and prediction can be used as effective strategies during reading comprehension. Students revisit their reading, actively applying these inquiry skills to the reading sample. Students then evaluate the scientific evidence from their investigations, interpreting their data, drawing conclusions, and revising initial hypotheses in light of their new knowledge from the reading. Finally, students will assess their understanding through the use of metacognitive strategies, the K-W-L technique, and written drafts.

The Transformation phase centers on the communication of student knowledge through composition, demonstrated in both oral and written formats. Writing tasks can be short compositions, longer reports, reader-response journals, scientist notebook entries, or traditional laboratory reports—the key is that the writing assignments must contain specific requirements structured to obtain a new product necessitating the transformation of student knowledge gained from readings and investigations, rather than simply a reiteration of facts and methods. Writing in this manner promotes the reinforcement of reading, capitalizing on the well-known "reading and writing connection" (Nelson and Calfee 1998), as well as serving as a communication tool. Oral reporting in this phase serves to give students the opportunity to share their experience and also provides students with a gauge of how their work compares to others—a modeling approach crucial to the development of students toward higher levels of achievement.

Key inquiry skills to unlock reading comprehension

The previous definition of science inquiry from the NRC provides us with a list of targeted inquiry behaviors that can be applied to reading comprehension. The notion here is that we, as teachers, want to create inquiring students who will apply this model of active learning to science, reading, and all subjects. Figure 2 provides a list of inquiry skills and how and when they may be applied to science reading activities.

Closing thoughts

By strengthening students' science inquiry skills and showing them their applicability to reading, we are introducing students to a new way of thinking about science and text. In essence, rather than teaching them to read, we are teaching them to learn from reading. Doing so in the middle grades simply "makes sense"—students of this age have reached a level where they are capable of reflective thought and are encountering the significant challenge of multiple teachers, subject areas, and text demands. By providing them with a common and useful strategy for learning from and comprehending text—not just in science, but in any subject area—we are supporting them to achieve at their highest levels in middle school and beyond.

References

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academy Press.

Norris, S.P. and L.M. Phillips. 2003. How literacy in its fundamental sense is critical to scientific literacy. *Science Education* 87: 224–240.

Nelson, N. and R.C. Calfee. 1998. The reading and writing connection viewed historically. In *The reading and writing connection: Ninety-seventh yearbook of the National Society for the Study of Education*, eds. N. Nelson and R.C. Calfee, Vol. 97: 1–52 . Chicago: University of Chicago Press.

Vygotsky, L.S. 1978. *Mind in society: The development of higher psychological processes*, eds. M. Cole, V. John-Steiner, S. Scribner, and E. Souberman. Cambridge, MA: Harvard University Press.

Vygotsky, L.S. 1986. *Thought and language*. Trans. A. Kozalin. Cambridge, MA: Harvard University Press.