Journal of Adolescent & Adult Literacy 55(7)
April 2012
doi:10.1002/JAAL.00069

(pp. 580–586)

COMMENTARY

# Reading, Writing, and Thinking Like a Scientist

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Imagine our surprise when we, Gina and David (first and second authors), both having spent much more time working on literacy issues at the elementary than the secondary level, received an invitation from the *Journal of Adolescent & Adult Literacy* to write a column outlining what our work has to say about adolescent literacy.

After the initial wonderment, we concluded that the editors might want us to share insights from our work on disciplinary literacy with elementary students in hopes that the lessons we have learned might prove useful, or at least provocative, for those who work on matters of language and literacy within disciplinary contexts for older students. So, optimists that we are, we decided to focus our commentary on just that expectation: "What High School Juniors Can Learn From Second Graders About Reading, Writing, and Thinking Like a Scientist."

For the last eight years, we have been involved in work on the integration of science and literacy instruction using a particular model borne of the questions, "How can reading, writing, and language be used as tools to enhance the acquisition of science knowledge and inquiry processes?" and "How do reading, writing, and language benefit from being put to service in pursuit of the goals of inquiry based science?"

We have been trying to answer those two questions as we have engaged in a classic research and development program to build, revise, and evaluate the efficacy of a National Science Foundation–sponsored integrated elementary curriculum program, *Seeds of Science/Roots of Reading*. In this commentary, we will discuss what we (and others) have learned about literacy and disciplinary learning with younger students and how these lessons might inform the conversation about disciplinary literacy at the secondary level. We will stick closely to science—because it's what we know best—with some allusion to other domains.

## Lesson 1: Lead With Inquiry

In our work on science-literacy integration, we have taken the stance that literacy instruction and literacy activity in science should be positioned in supporting roles—as tools that enhance the quest for knowledge and expertise in a discipline.

It may at first seem odd that elementary reading educators have so strongly embraced the decentering of text. But the body of work on elementary students' engagement with literacy texts and tasks in science has persuaded us that moving conceptual understanding, firsthand activity, and exploratory discourse to the center, while positioning text and language experiences as tools for involvement in inquiry and the development of conceptual understanding, actually benefits literacy development—and, of course, science learning.

Work on science-literacy integration at the elementary level has demonstrated that the *motives* for reading and writing inherent to disciplinary activity and the *challenges* associated with reading and writing in science support literacy development. Moreover, research on science-literacy integration has demonstrated that bringing compelling motives to reading is as important as direct teaching of reading strategies and text features.

For example, Purcell-Gates, Duke, and Martineau (2007) examined the impact of explicit teaching of genre features of nonfiction science text genres and the impact of authenticity of literacy activities on second- and third-grade students' growth in reading and writing the genres. Purcell-Gates et al. defined explicit teaching of genre features as naming, describing, or explaining the function of genres (in this case, procedural texts and informational texts) and genre features, such as headings, typical verb constructions, and common visual displays.

Purcell-Gates and colleagues (2007) defined authentic activity as (a) reading and writing text genres that occur outside of a school-like learning context and (b) reading and writing those genres for purposes other than learning to read and write them (e.g., reading for information or writing to communicate information to someone who wants it). The researchers found that the teaching of text features did not predict growth (except for one outcome in interaction with authenticity), but that authenticity predicted growth in both reading and writing.

The Concept-Oriented Reading Instruction (CORI) program (e.g., Guthrie et al., 2004) has demonstrated positive effects for comprehension instruction embedded in ongoing science investigations. The focus of CORI is supporting reading engagement and the use of comprehension strategies. CORI researchers have further found that embedding direct instruction of comprehension strategies in extended, knowledge-building science investigations (investigations that include firsthand experiences) supports students' literacy development better than direct instruction of comprehension strategies that are divorced from the context of explicit and theme-based knowledge-development.

**Bringing compelling motives to reading is as important as direct teaching of reading strategies.**

In a set of studies of CORI in third-grade classrooms, Guthrie et al. (2004) found that students involved in CORI outgrew students in a traditional instruction condition and an explicit strategy instruction (SI) condition on measures of comprehension, strategy use, and reading motivation. Students in the SI classrooms were taught the same comprehension strategies as CORI students, but reading instruction in CORI involved more use of science-knowledge goals to provide a purpose for strategy use, hands-on activities, autonomy supports (such as choice in the selection of books to read), and collaboration.

Romance and Vitale (1992, 2009) studied the implementation of an instructional intervention, In-depth Expanded Applications of Science (IDEAS), which replaced the time usually devoted to English language arts instruction with two hours of daily science instruction that included attention to reading and mapping ideas from text and to writing in addition to firsthand science activities.

The IDEAS comprehension program includes text analysis, which directs students' attention toward understanding text structures, such as cause-and-effect, and using prior knowledge to build new knowledge while reading; concept-mapping to organize knowledge encountered during reading; and writing summaries based on the concept maps. The researchers have found treatment effects for the intervention on the Iowa Test of Basic Skills Reading and Science subtests across the studies with students in grades 2 to 5, and, in the 2009 study, they found transfer effects of the intervention when students reached grades 6 and 7.

### The Common Thread

The common thread across these studies is that students were engaged in reading meaningful texts for meaningful purposes in knowledge-building contexts. In our own work, we have taken this to mean that it makes little sense to try to teach comprehension of science texts outside of the knowledge-enriching and inquiry-driven context of extended science investigations. In such contexts, the need to read—and to invoke a wide array of reading strategies in doing so—arises naturally without artificial curricular accommodations to create opportunities for strategy use.

Students who have few opportunities to use reading strategies for the purpose of supporting authentic reading might doubt the usefulness of these strategies (Turner & Paris, 1995); but science concepts are often challenging, and reading in the interest of understanding them demands persistence, attention, and the application of strategies. That is, reading to learn and investigate is rich with opportunities to encounter the very struggles that seem to catalyze reading development and represent reading as the meaning-making process that it is.

All too often, especially in high fidelity implementations of basal programs, reading and writing strategies are taught as content-free routines that can be applied to *any* text. They should be taught in exactly the opposite way—as tools that help readers unlock the meanings of *particular* texts in the interest of *particular* knowledge and inquiry pursuits.

Relatedly, the pursuit of curiosity and the development of expertise through reading are powerful factors in sustained motivation to read (Baker & Wigfield, 1999; Wigfield & Guthrie, 1997). The CORI program has offered particularly compelling evidence that, even when groups of students are taught the same strategies, applying the strategies as students read to answer questions in science has resulted in greater gains in students' ability to use strategies effectively and greater gains in intrinsic motivation to read (e.g., Guthrie et al., 2004).

In the effort to develop disciplinary literacy, or even to teach students to engage with texts of various genres, it makes little sense to remove content-area instruction from its natural and rightful contexts of application—the subject matter classes in science, math, social studies, and literature. Here we regard literature as a discipline with its own knowledge goals, discourse conventions, rules of evidence, and cultural traditions. We are tempted to call for the end of special classes for how to read in any content area, to be replaced by instructional activities for how to read within each and every particular content area.

While this would be a difficult vision to realize, isolating the mechanics of reading content-area texts from contexts of application invites unproductive understandings about reading and disciplinary knowledge and activity. Perhaps the new Common Core State Standards (2010) will help us move in that direction with their insistence that students beyond grade 5 learn how to apply reading and writing practices in somewhat different instantiations to the disciplines of literature, history, and science.

### Managing the Teachable Moment Dilemma

Every teacher can be paralyzed by the teachable moment dilemma: If you want students to enact a summarizing strategy, do you wait for the perfect "authentic" situation to arise so that you can teach it at the point when students could really use it? Or, do you engineer a lesson for everyone in the class on how to create a summary, at a time and with a text that you (or the series you use) have chosen in advance?

Our answer is a compromise: (a) engineer teachable moments by using baffling texts that create the need to use a clarifying or other sense-making strategy for everyone, including you; and (b) always keep a minilesson for every useful strategy in your hip pocket so you can pounce on real teachable moments whenever they present themselves—for a whole class, a small work group, or an individual student.

## Lesson 2: To Thine Own Discipline Be (Mostly) True

It is not radical—or new—to suggest that reading, writing, and talk are core practices of science, closely linked to inquiry and the development of scientific knowledge. Although science educators continue to express concern that the use of textbooks often replaces inquiry experiences in science class, there is broad acknowledgement in the science education community that literacy plays an important role in learning and practicing science (e.g., Yore et al., 2004).

The National Research Council's (2011) new framework for science education includes a detailed discussion of this relationship, noting that "reading, interpreting, and producing text are fundamental practices of science in particular, and they constitute at least half of engineers' and scientists' total working time" (pp. 3–19). By contrast, the questions of where and how students should be taught to read and write discipline-based texts and how much disciplinary literacy should mirror the literacy practices of professional scientists—what they read and write and how they read and write— is contested ground.

Three years ago, Moje (2008) used this commentary to advocate for the development of "disciplinary literacy instructional programs" that build students' understandings about how knowledge is created in disciplines (p. 96). Heller (2010) responded by defending "amateurism" and the idea that disciplinary literacy instruction should be left for college majors and graduate programs, while disciplinary study for high school students should be viewed as part of a general education program designed to precede college—one that pays little mind to ways that professionals in the discipline read or reason.

One outcome of the recent interest in disciplinary literacy has been a deeper understanding of the relationship between literacy practices and the development of knowledge in disciplines (Heller & Greenleaf, 2007; Moje, 2008). Research in disciplinary literacy has started to demonstrate how reading and writing differ across disciplines and how these differences are related to the nature of the disciplinary ways of reasoning and inquiring.

For example, Shanahan and Shanahan (2008) examined the reading processes of professional scientists, mathematicians, and historians as they read texts in their respective areas. The researchers found that the experts in each discipline approached texts differently and leveraged a different set of reading strategies.

To illustrate, whereas mathematicians attempted to read through the text to get at its real message, and historians attended to possible sources of bias, scientists tended to examine the credibility of the work that lay behind the text—who produced it, where, and for what purpose—and tended to examine the procedures used to obtain the results.

**Reading science text as received fact... simply would not be "doing science."**

Shanahan and Shanahan (2008) suggested that differences in the reading practices of the disciplinary experts are related to the values, norms, and methods of scholarship within each discipline. Historical scholarship is characterized by retrospective analysis and interpretation of historical documents. Historians then must read for author's perspective, because this form of inquiry leaves open the possibility that an author's perspective will lead to selective analysis and biased interpretation. As a result, we suggest that reading historical texts as received fact without thinking about issues of interpretation, authorship, and context simply isn't doing history.

If it is true that reading and reasoning in the disciplines are inextricably linked in this way, we should be careful about assuming that any processes (call them strategies, skills, routines, or practices) automatically generalize from one discipline to another. We do not claim that they will not or would not generalize; indeed we are ready, even happy, to encounter overlap in the reading practices of different disciplines.

However, given that evidence seems to be stacking up on the side of uniqueness, rather than commonality, we think that we are better off as a profession to begin our instructional journey into the disciplines by assuming that processes won't generalize. Then if it turns out that they do, that's a pedagogical bonus. But caution should prevail until we have more data.

In our work on science-literacy integration, we have taken the position that reading science text as received fact without simultaneously coming to understand the methods of inquiry that produced those facts and the nature of science as a way of answering questions about the natural world simply would not be "doing science." Language and literacy should support students' engagement in inquiry experiences; and those experiences must involve forms of data gathering and reasoning about data that professionals in the discipline use to answer questions of interest.

In the instructional program we developed, we involve second- through fifth-grade students in reading and writing as they plan, conduct, and make sense of their firsthand investigations. In doing so, we use every opportunity to share with students the values, dispositions, forms of reasoning, and methods of inquiry that are part of scientific knowledge building.

For example, students might conduct, as they do in one of the units, an inquiry about the composition and formation of different sand samples. As they conduct these inquiries, they read an account about a professional ocean scientist who describes his own investigations, including the processes that he uses to record information and reason about the evidence he gathers. The students are asked to use the scientist's process as a model for their own and to compare their results with his—just as professional scientists use the work of other scientists to make sense of their own results and interpret their results in the context of relevant lines of inquiry in a field.

## Lesson 3: Texts Should Make Science Inquiry Smarter, Not Dumber

This insight about texts in disciplinary literacy is really an extension or corollary of the second insight about fidelity to the disciplines. It follows from the common practice of foregrounding textbooks in science education in ways that push firsthand inquiry to the margins.

This exclusionary practice makes science dumber for the reason we already stated: It portrays science as a set of received facts rather than a set of dispositions that guide students in making meaning of their observations of the natural world. Texts make science smarter when they support, rather than eclipse, involvement in inquiry and other forms of meaning making.

As literacy educators, we should champion text by assisting our disciplinary colleagues in the judicious use of texts in pursuit of the larger goal of science pedagogy. And we should always be the first to point out how text can be abused as a tool for learning by even the most well-meaning educators.

One unsettled issue at the heart of disciplinary literacy regards the kinds of texts that students should read as they acquire disciplinary knowledge and engage in disciplinary activity. In science, at least, this question has been the subject of some debate (Norris et al., 2009; Osborne, 2009; Phillips & Norris, 2009).

The issue of texts in elementary-level science has been contested for decades and, until recently, resulted in a stark divide between textbook-driven science and inquiry-driven science. Those on the side of inquiry have pointed out that there is a great deal of potential for misconceptions about science in science textbooks, and that not all texts support involvement in inquiry. For example, in an examination of science textbooks, Penney, Norris, Phillips, and Clark (2003) found that the textbooks presented science as a set of factual truths and included little in the way of argumentation or information about how the "facts" were derived through inquiry.

A number of alternatives to textbooks have been proposed, ranging from high-quality science trade books (Smolkin, McTigue, Donovan, & Coleman, 2009), to scientific papers rewritten to be understandable to students (e.g., Phillips & Norris, 2009), to texts that reflect those that media use to report about science to the public (Osborne, 2009). In the CORI program (e.g., Guthrie, McRae, & Klauda, 2007), students read a range of science trade texts, including stories, informational books, and poems, in support of their investigations. In IDEAS (e.g., Romance & Vitale, 2001), students read from science textbooks and trade books.

In our work on science-literacy integration, we have developed and selected texts with an emphasis on their roles in teaching science as the interplay of content and process and in involving students in science inquiry (Cervetti & Barber, 2008). The texts often resemble those that scientists use as they engage in inquiry, such as handbooks, field guides, and graphic representations of data.

But students also read informational and narrative texts that look less like those that scientists read in their professional lives. For example, students read to learn about inquiry methods that they can apply to their investigations, much as scientists do. However, rather than reading the methods sections of scientific papers, students most often read about others' methods of inquiry in narratives that describe the investigations of practicing scientists and other student scientists.

Students use these narratives as models in order to engage in their own investigations. They also consider what the descriptions of others' investigations communicate about the nature of knowledge building in science—things like the role of evidence, the role of disagreement within the scientific community, and the role of creativity in inquiry.

What has mattered to us is involvement in inquiry and fidelity to the ways that language and literacy support inquiry—for students and practicing scientists. The problem with positioning students solely as receivers of facts presented in scientific textbooks is that the approach undermines our ability to communicate the nature and dispositions of science in ways that reveal the internal logic of knowledge production in the discipline, including what many would regard as the quintessential scientific disposition—to bring a skeptical mind to the table when discussing what (and how) we know about the natural world.

## Final Thoughts

When we initially outlined our three lessons learned, we believed that they were independent insights. And, had space not been an issue, we knew that we could have additional insights—about the relationship between vocabulary and conceptual knowledge (words are not the point of words, ideas are!) or the relationship between discourse and reasoning (science is a discourse about the natural world!).

But as we have unpacked these insights, we have come to the conclusion that they are really just three variations on a common theme—position literacy vis-à-vis science as a set of tools that supports students in using the methods and lenses of science to make sense of the natural world. In science—in any discipline—reading, writing, and language should not be the goals; instead they should be indispensable tools that students use alongside discipline specific tools.

In order to realize this vision, much more work is needed on texts and the literacy practices that support disciplinary reasoning, participation, and critique. Most of all, we need to know more about how to support teachers in capitalizing on (and occasionally engineering) teachable moments as they bring the tools of literacy to disciplinary learning.

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