Helping Students Learn From Texts

In this chapter I provide some background from research on why reading science content, both textbooks and primary literature, is so difficult for students, and why they have problems learning meaningfully from reading.

The posting below, a bit longer than most, looks at ways to help students better comprehend "information-rich text" often found in science and engineering courses, but elsewhere as well. It is from Chapter 3 – Helping Students Learn From Texts, in the book, *Teaching Undergraduate Science: A Guide to Overcoming Obstacles to Student Learning,* by Linda C. Hodges. Published by Stylus Publishing, LLC 22883 Quicksilver Drive Sterling, Virginia 20166-2102. https://sty.presswarehouse.com/books/features.asp.

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One of the biggest surprises that new faculty experience is that most students rarely read before coming to class – or after attending class for that matter. This observation is true across disciplines, but it may be even more of a problem in science classes. In one study, college students reported resorting to reading their science texts only in desperation as they studied for exams (Bonner & Holliday, 2006). Even if students do read the textbook at some point, their understanding of the key ideas in it may bear little resemblance to what we want them to take away.

Two closely interrelated problems associated with students reading science textbooks or primary literature are motivating them to read in the first place and helping them understand what they read when they do. If students find the reading too difficult to understand, they will be less motivated to read it. And if they do not feel that reading will help them learn, they are less likely to try. Yet learning to read science texts is important on so many levels, especially in enabling students to learn on their own.

If biology faculty are a representative sampling, faculty do value having their students learn skills such as effective reading. In one study of 159 college and university biology faculty, respondents rated reading as a very important skill for science students (Coil, Wenderoth, Cunningham, & Dirks, 2010). Faculty in this study, however, felt that they did not spend enough time teaching such skills. We can readily infer the primary reason that faculty cited: Teaching process would take too much time away from teaching content. The authors of this study note, however, that it accomplishes little if we teach students content but they lack the thinking skills necessary to master that content. Another challenge in teaching the processes of reading science texts to our students, however, is that as experts we no longer explicitly recognize the sophisticated mental moves we make to generate meaning from our complex disciplinary texts. These processes have become automatic and constitute another example of expert blind spot. Before we can help our students, we may need to uncover our own reading strategies.

In this chapter I provide some background from research on why reading science content, both textbooks and primary literature, is so difficult for students, and why they have problems learning meaningfully from reading. I also share my thoughts on the implications from these ideas for choosing and writing textbooks. The strategies section then offers a range of ways to develop students' ability to read science based on this research.

Key Ideas From the Research

Our students have been reading since they were small children, so this chapter on reading may seem like an odd addition to a book about teaching college science. Most of what students read, however, is of a very different style of writing than science texts. Three key ideas from the research can inform us as we teach students the vital skill of how to read science writing.

1. *Science writing is so different in style and so packed with information and new vocabulary that it is hard for students to know what they should learn from it.* Students are most accustomed to reading narratives, the style of writing found in fiction and on many websites. Much academic writing, and especially science writing, is classified as informational or expository text, text that has a much denser structure and a more impersonal, authoritative stance. The vital question in reading – "What is this reading about?" – gets lost as students try to unravel ideas simply at the sentence level. Our students may also not have (or do not remember) the prerequisite prior knowledge to understand the text at a deeper level. Furthermore, they may not recognize that they need to use different reading approaches to understand science than they use to understand many other forms of writing.

2. *The cognitive load of reading science texts is such that students typically do not recognize what they don't know from the reading. Even if they do, they often don't know how to address their lack of understanding productively or are not motivated to do so.* College students typically learn to read information-rich texts by trial and error, cobbling together a variety of strategies from reading narrative texts over years of education (Shanahan, 2004). These strategies are typically not very efficient or effective when reading science. Comprehending information-rich text requires us to think about our thinking – to be metacognitive – in two distinct ways. First, we must evaluate whether the text makes sense within itself and within the dictates of our prior understandings. Second, we must regulate our thinking to solve whatever problems we have in understanding the text. To learn, students must focus on a number of ideas simultaneously – new concepts and definitions and the prior knowledge needed to make sense of them. This balancing act can easily exceed the cognitive load capacity of working memory. And this process depends on students having the requisite prior knowledge to understand something new. Even good readers can have difficulties processing text deeply when, as is often the case, the texts have left out critical steps in explanation.

3. *Students often assume that the purpose of reading any science writing is to learn facts. They do not realize that they can and should question what they read, nor do*

they know how. When we have students read primary literature, we want them to analyze and evaluate what they read, not just accept the text as fact. We want to familiarize them with the way that scientists construct and communicate new knowledge. When teaching from primary literature, we need to guide students in reading for critique and not just for learning.

The challenges that students have in learning from reading science writing thus arise from several main factors discussed more fully in the following sections:

- Differences inherent in science writing style and conventions
- Cognitive load associated with reading complex material
- Not understanding the purpose in reading
- Not being motivated to read

Differences Inherent in Science Writing Style and Conventions

In science writing, all the components of reading take on new complexity. Let's look at each aspect of science writing and how they differ from those of narrative writing.

Vocabulary. The number of new terms in secondary school science texts (approximately 1,000 to 3,000 or more) often exceeds the number recommended for foreign language courses for that age group (Groves, 1995; Yager, 1983). Many words are unfamiliar, being derived from Latin and Greek, languages that few modern students know. Other words are misleadingly familiar. For example, the term *evaporate* in common usage means "to disappear," but in chemistry it means "to change states from a liquid to a vapor." So as a substance evaporates it does become invisible in most cases, but it does not truly disappear, a conflation that could generate a misleading mental representation for the novice learner (Shanahan, 2012). Think also about the subtle yet important differences between the way scientists and laypeople use terms such as *uncertainty*, *sign*, and *theory*, for example (Somerville & Hassol, 2011). Such so-called dual meaning vocabulary can cause confusion as students are developing understanding (Song & Carheden, 2014).

Writing style. Science writing uses a number of conventions that make it concise, precise, and compressed (Snow, 2010). Typically sentences offer limited explanation or linking to past ideas needed for understanding. This description is especially true of primary literature, but science textbooks often skimp on explanations as well. Primary literature often compresses ideas of two to three sentences into one by using grammatical maneuvers such as converting verbs into nouns. In addition, the impersonal and authoritative voice adopted by science writing creates a distance that disconcerts novice readers and that they find difficult to adopt in their own science writing (Snow, 2010). In essence, academic writing is much less conversational than other common writing forms, and it often overtaxes students' experience with and expectations of reading.

Use of graphics, equations, symbols, and formulae. Science writing represents ideas not only in text but also in other forms that are foreign to students. Thus, students may routinely skip over graphs and tables in favor of text. Textbooks may further confuse the issue by including extraneous images purely for entertainment. Formulae, both mathematical and structural, are often a true foreign language for students. Consider further the variety of ways that we represent the same idea mathematically or graphically or the same molecule structurally. One of the skills we need to cultivate in students is called "fluency," the ability to translate ideas from one form of representation to another – for example, words to symbols and graphics to words (Shanahan, 2012). Unfortunately, students often do not realize that the abilities to interpret the information in such graphics and, conversely, to express text in graphic representations, are crucial for their understanding of the content and process of science.

These issues related to students' difficulties in learning from science writing spill over naturally into their difficulty in writing science. I discuss ways to support students in writing science in chapter 8.

Cognitive Load Associated With Reading Complex Material

We want our students to not only understand what they read but also, obviously, learn from their reading (van den Broek, 2010). But these two cognitive demands can create a "split focus" (Goldman, 1997). Comprehension requires the reader to generate an accurate mental representation of what she's reading. She must call on prior knowledge to translate the text and construct a mental depiction of the situation being described. Learning extends that activity by having the reader add to or modify existing background knowledge. The nature of reading actually poses a conundrum for students learning science from articles and books, in that prior knowledge is essential both to comprehend and to learn from text, and prior knowledge in science is exactly what students do not have (Rouet & Vidal-Abarca, 2002). Even more advanced students, who should have the requisite prior knowledge, may not have retained that information in a robust enough way to access it readily while reading.

In addition, not everything that a reader is reading can be dealt with simultaneously in working memory. The working memory model (discussed also in chapters 2 and 4) posits a limited capacity for the number of "units" of information (concepts, contexts, connections) we can keep in working memory at once (Baddeley, 1986). One theory of reading comprehension (Kintsch, 1988) claims that we process what we are reading in cycles. In each cycle we can only handle about the equivalent of one sentence at a time in working memory. We construct meaning by cycling ideas through our working memory, importing small amounts of each previous cycle into each subsequent cycle to deal with it. As information moves into and out of focus in working memory, readers are pressed to make meaning of it given the information in play at the time. Most science textbooks and articles present information and relationships so densely that students' focus cannot keep pace (van den Broek, 2010). The practical consequence of these competing demands is that college students often do not read science with the depth of processing needed to make meaning of it.

Readers have implicit standards to judge whether they sufficiently understand what they are reading or if they need to draw on information from prior knowledge (van den Broek, Risden, & Husebye-Hartmann, 1995). Unfortunately, it is very easy for readers in general and students in particular to experience the "illusion of knowing." In this situation, we make a partial match between the reading and our prior understanding, leading us to assume that we understand something that we do not. One study of this phenomenon in college students showed that even students with extensive background knowledge experienced a false sense of knowing when they read well-written text (McNamara, Kintsch, Songer, & Kintsch, 1996). In another study of college students, the problem of the illusion of knowing was more apparent, not surprisingly, when students were asked to engage in a shallow processing task for a difficult reading (deciding if the text was understandable) than when they were assigned a deeper processing task (summarizing the text for a fellow student; Schommer & Surber, 1986). Unfortunately, students' accuracy of monitoring their understanding is typically poor (Dunlosky, Rawson, & Hacker, 2002).

Why is it so difficult for students to recognize whether they understand an idea? One important factor that affects reading comprehension is whether students focus their attention just at the sentence level or if they are able to keep the global goal in mind – that is, "What is this reading about?" One study (Rawson & Dunlosky, 2007), for example, showed that college students could not accurately predict how well they would answer questions over a textbook reading. This finding was true even when they were shown the correct answer and their own answer before making the prediction! Kintsch's model (1988) may provide one explanation for this surprising finding. According to this theory, new information coming in from our reading displaces some parts of the meaning we constructed from each prior reading cycle. Thus we may lose information critical for understanding. When students in the Rawson and Dunlosky study (2007) compared their written response to the correct answer, for example, they might see similarities in sentence structure and terminology and overlook key underlying differences in meaning (Rawson & Dunlosky, 2007). This finding illustrates how great an obstacle cognitive load is to students' abilities to process text for meaningful learning.

Not Understanding the Purpose in Reading

Novice learners in our fields may not consciously recognize that people read with a purpose. And even if they do, they probably do not have the same purpose in mind for their reading as we have for them. Students may recognize only two purposes to reading: long-term preparation for courses or careers and immediate preparation for a test (Elshout-Mohr & van Daalen-Kapteijns, 2002). They may not share our expectations that they read to develop understanding or to evaluate new ideas. In fact, many students would find the thought of reading a primary research article with the goal of critique an alien, if not frightening, concept. Unfortunately, their prior school experiences may have unwittingly contributed to this situation. Secondary schooling in science may too often ask students to accept on faith something they read because they do not have the background to generate true understanding. But this requirement inculcates a habit of students *not* reading for in-depth understanding (Otero, 2002).

When we then ask our students to make connections requiring higher-order processing, their requisite comprehension may be lacking. Think how much more unprepared they will be for reading for critique in our more advanced courses if they have been trained to accept science as a set of facts to be learned. To improve students' ability to self-regulate their reading – monitoring their comprehension, checking text for inconsistencies, and thinking about possible implications or deficiencies – we need to give them guidance in how to read and question the text.

What is the purpose in having students read the textbook before class? After all, students commonly tell faculty that they understand our lectures better than the text. Their assertions are no doubt true. We speak conversationally, define terms, make connections to prior knowledge, ask them questions as we go along, and maybe even crack some jokes (for better or worse). Unfortunately, however, if we are "first exposure" to the material for them, their understanding cannot deepen very much from our lectures. During class we want to expand their understanding, extending and multiplying neuronal connections in their brains. But if they have not read before class, they have not activated key prior knowledge. Nor have they begun to make connections that help offset cognitive overload during the lecture and allow meaningful learning to occur. In a way, students and faculty have different purposes in mind for reading assignments. Motivating students to read requires us to make clear our expectations for their reading and to provide incentives for them to tackle this work.

Not Being Motivated to Read

As I discussed in chapter 1, motivating students depends on at least two complex ideas: their perceived value of the goal and a realistic belief in their ability to achieve the goal (self-efficacy). So students need to want to focus their attention on the reading and to feel that they can get something out of it if they do. A common way that faculty motivate students to read text is by holding them accountable in some way for doing so. Giving reading quizzes or requiring homework related to the reading provides extrinsic motivation. Some students value the grade enough that they will make the effort to do the reading. In general, however, generating *intrinsic motivation*, or the desire to do something for an inherent sense of satisfaction, is preferable when possible. If we use the reading in interesting ways in class, for example, by engaging students in real-world problems drawing from ideas in the reading, we can start to foster an intrinsic sense in students that the work of reading has value.

A closely related and perhaps more important way to motivate students to read is to increase their belief in the ability to learn from reading. The complexity of reading science, as well as the habit that students may have of reading science as facts to be memorized, can hamper their ability to learn from reading. If they are reading superficially, then they will not glean from the reading what they need for our tests, and they will perceive the time they spent as wasted. We have the power to affect student motivation by providing models and guidance in effective reading practices. One way to model reading for students is to provide them with guiding questions for their reading. These questions mimic the way that students should approach their reading. They also provide explicit guidance in what exactly students need to be able to handle from the reading, thus supporting their motivation to read. A number of the suggestions in the upcoming strategies section build on the ideas of showing students how to question as they read and help them cultivate productive metacognitive and self-regulating habits in reading.

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