Getting to the Root of the Problem: Teaching Reading as a Process in the Sciences

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This chapter examines how reading can be taught in high school and undergraduate science courses. Teaching reading in the content areas is important because students' reading skills are intrinsically connected to their writing skills and their subject-specific content knowledge. In order to improve students' reading abilities, the act of reading needs to be a more visible and frequent part of high school and college courses. The chapter defines college-level reading as acquiring genre- and discipline-specific "reading processes" that have recursive stages of pre-reading, reading, and revised reading. The extended examples in this chapter demonstrate how high school and college science teachers can teach students particular reading processes that can help them comprehend and analyze three common genres assigned in science courses: the popular science trade book and magazine article, the science textbook, and the empirical research article. The reading activities suggested emphasize the rhetorical nature of these scientific texts. This chapter argues that science teachers need to rely on frequent modeling and direct instruction in order to make the process of reading scientific texts more transparent to students.

I don't mind dandelions. In contrast to my neighbors' yards, deep-dark green swaths of grass, unmarred by weeds, my yard is speckled yellow. As anyone who's tried knows, it's a pain to get rid of dandelions. A dandelion's taproot buries quickly into the ground, making it nearly impossible to rip the plant out with your bare hands. You have to get down on your knees, trowel in hand, and dig the dandelion out – flower, stem, root, and all.

And this work takes quite a bit of effort. Some people get around that effort by dousing their lawns in herbicides; others, like myself, just mow down the dandelions when they turn scraggly and bald. But mowing is a temporary solution. Just days later, the taproots left just under the surface of the soil sprout anew, and the dandelions repopulate my yard.

I'm talking about dandelions here because I find them a useful metaphor when I talk with faculty across the disciplines about the connections between our students' reading skills, their writing skills, and their subject-specific content knowledge. The faculty conversations I hear in offices and hallways often fail to take into account the deeply rooted *reading* issues that contribute to problems in students' content knowledge and writing, problems that range from papers riddled with grammatical errors, exams or in-class discussions that demonstrate incomplete understanding of course material, written arguments that lack or misrepresent evidence, and plagiarism. Because students' underground reading issues aren't addressed, the "solutions" to student content knowledge and writing problems that are often discussed, from textbook pop quizzes and grammar drills to plagiarism detection software systems such as SafeAssign and Turnitin.com, are as temporary and ultimately ineffective as mowing down a lawn full of dandelions.

As the editors explain in the introduction to this collection, high school and undergraduate students have difficulty reading disciplinary texts. Part of this difficulty can be traced to students having ineffective or no *reading processes*, processes that are nuanced and flexible enough to use in a variety of rhetorical situations. Without these processes, students read shallowly and narrowly, miss important genre cues, and cherry-pick facts contained in individual sentences rather than comprehending whole-text arguments (Jamieson, 2013; Horning, 2011; Howard, Serviss, & Rodrigue, 2010). These unsophisticated reading processes, coupled with the sophisticated writing prompts that faculty in the disciplines assign their students, can lead to poor student performance or student writing that might not accurately reflect students' knowledge of and engagement with the subject matter. What I'm arguing is that in some cases, a student's error-ridden or plagiarized writing, or that student's lack of content knowledge, can be symptoms of a much larger reading problem. Faculty members in all disciplines need to develop pedagogical strategies that will treat the problem – our students' lack of sophisticated reading processes – not the symptoms.

In this chapter, I explain how faculty in the sciences can teach students reading processes that can help students decode, analyze, and discuss disciplinary texts. I first define college-level reading by naming and describing stages of reading. In order to read complex, discipline-specific texts, students must learn strategies for what I term the *pre-reading*, *reading*, and *revised reading* stages. These stages are not linear or discrete. Rather, the stages of a sophisticated reading process overlap. Expert readers are recursive in how they move through these stages, circling back as they read and re-read a text for different purposes. Then, I describe activities that science teachers can use to teach students how to read the three genres high school and undergraduate students most often encounter in their science courses: 1. the popular science trade book or magazine article, written for a general educated public audience (including collections such as *The Best American Science and Nature Writing* and articles from publications like *Scientific American*, *Popular Science*, and *Wired*); 2. the science textbook; and 3. the empirical research article (published in peer-reviewed scientific journals such as *The New England Journal of Medicine*, *Science*, and *Chemical Reviews*). All the activities I describe underscore the rhetorical and contingent nature of scientific knowledge. Too often, students regard scientific texts as collections of facts about biological, chemical, or physical processes. When students think of scientific texts as merely content, they miss out on discovering how these texts can help them participate in the larger scientific process of posing hypotheses, collecting and analyzing data, making claims and conclusions from that data, and considering and challenging alternate methods and conclusions. The activities and assignments I suggest in this chapter show how emphasizing stages of the reading process (*pre-reading*, *reading*, and *revised reading*) can open up scientific texts to high school and undergraduate students, introducing them to the ways in which scientific knowledge is created, communicated, and circulated. If students understand the nature of the texts they read, they can read the texts with more alacrity, distinguish a text's key claims and information more easily, and write about the texts with more sophistication.

Definition of the Reading Process

All faculty – not just those in English departments or first-year writing programs – need to teach undergraduate students how to read. Rhodes (2013) makes this point and uses the assessment data from her first-year writing program to show that, contrary to what many faculty expect, students come into college with weak reading skills. In response, Rhodes argues that faculty across the disciplines need to "explain explicitly why and how we want students to address the texts we assign." (Rhodes, 2013, para. 6) Rhodes' argument here – that faculty must clearly explain to students the *purpose* of reading assigned texts – also draws on Horning's (2007) research on undergraduate students' weak reading skills. Rhodes explains that students who are not "good readers" are lacking "reading processes." (para. 2; para. 22) One of the primary reasons students come to college with poor reading skills is that they do not have sophisticated reading processes that help them comprehend, analyze, and interpret complex texts. College-level reading processes are "recursive," Rhodes argues, "requiring dialogue and feedback, along with revisions of perceptions and readjustments" (para. 22). Reading, Rhodes argues, is not a simple, one-step activity. It requires complex, critical thinking skills. In her description of reading processes – processes that depend on dialogue, feedback, and revision – Rhodes uses similar language as scholars who have described the writing process. This parallel between a concept of a *reading process* and the concept of a *writing process* is helpful for developing a reading pedagogy that is useful for faculty across the disciplines.

Writing process theory fundamentally changed how teachers teach writing and faculty's expectations for student writing. The advent of writing process theory in the 1960s, 1970s, and 1980s, and then the arguments for writing across the curriculum programs that quickly followed (including theories developed by Nancy Sommers [1980], Frank D'Angelo [1987], Susan McLeod [1989], and David Russell [1992]) shifted attention from the product of student writing to our students' writing processes. The writing process movement gave faculty and the discipline of writing studies a language to talk about what writers *do* while writing. Research about writers' writing processes helped scholars dig under the surface to unveil the work that goes into producing a piece of written text. The research that helped develop theories and practices of writing across the curriculum named and described the rhetorical complexities of disciplinary-specific genres, which require different kinds of writing and writing processes. Writing process and writing across the curriculum theories changed faculty expectations for student writing: faculty within writing studies and many outside the field now expect that students will go through multiple stages in their writing process and that these stages will take time and look differently for different genres and students. Most faculty also understand the recursive and reflective nature of the writing process and the role of dialogue, conferencing, and workshops in this cyclical process. Some faculty build in overt instruction of the writing process, teaching students how they might develop an idea, outline an argument, and revise for a particular audience.

Defining and discussing *reading processes*, as the field of writing studies has done with *writing processes*, can change how faculty teach reading across the disciplines and faculty's expectations for student reading. The definition of a reading process that I outline below shares some of the theoretical assumptions that describe the writing process, and it builds from Rhodes' (2013) argument about the importance of direct reading instruction, Horning's (2011) explanation of the reading skills and habits of advanced or "expert" readers, and Freedman's description of a pedagogical model to teach reading skills to multilingual students (2013). Freedman's (2013) model consists of nine specific reading strategies that were taught to students dually enrolled in an East Asian Studies course and the English Language Learning (ELL) program at the University of Toronto. Though her case study focused on these ELL students, Freedman points out that these "methods were presented as techniques that can assist nearly every reader or writer, whether one is working in an additional or native language" (para. 10). The reading techniques presented to the students included previewing texts, skimming texts, using context to decode vocabulary, analyzing how a writer used sources and evidence in their argument, and making a visual map of the argument (Freedman, 2013). What is important about the strategies Freedman explains is that these techniques, coupled with low-stakes reading quizzes to test students' comprehension, help students treat reading as a deliberate, tangible process. The methods gave students a focus for their reading, and having multiple goals for reading (reading to analyze evidence, reading to distinguish a writer's argument from the argument of a cited source) encouraged students to do multiple re-readings of a text, which in turn helps increase comprehension.

One way to help our students think of reading as a process is to name and describe, as Freedman did in her case study, the specific strategies expert readers use when reading a complex text. These strategies can be loosely divided among three stages: *pre-reading*, *reading*, and *revised reading*. As with the terms used to describe the writing process (*pre-writing/drafting, writing*, and *revising*), the stages are neither linear nor prescriptive. Rather, this process is recursive (Gogan).

In the *pre-reading* stage, readers sketch out the general purpose, genre, and scope of the text. The goal of pre-reading is to begin placing the text in a larger context, doing the meta-textual and meta-contextual awareness work Horning (2011) describes. Some of the work readers do while pre-reading includes noting the organizational pattern of the text, referencing the table of contents to see the large-scale structure and moves of a book-length text, researching the publication and author(s) of a text to understand the disciplinary conversations that the text might participate in, quickly glossing the text's headings and subheadings, and glancing at the works cited to note familiar sources that this text cites. Pre-reading might include writing work: writing down general impressions of the text's genre, purpose, and audience, jotting down questions the reader might have developed from the preliminary pre-reading research, and listing terms and concepts that are repeated in the text's title, headings, and subheadings.

In the *reading* stage, readers read the text with a specific, genre- and discipline-specific strategy. For example, when reading an empirical research study, experienced readers do not read the article straight through: instead, they read the abstract first, then the conclusions and discussion, and then the methods, data, and literature review. Knowing how to read during the reading stage depends on work done in the pre-reading stage. Reading does not necessarily have to be close and precise in the reading stage; in fact, skimming and scanning texts quickly is a strategy often deployed by expert readers in all stages of reading (Horning, 2011). During the reading stage, readers often annotate a text, marking interesting and important claims, circling key words, and asking questions in the margins. A reader may read a text several times in the reading stage, and this reading may happen collaboratively. Readers may read out loud with a partner or in a whole class, or do "stop and reads," where they read a paragraph or passage, and then stop and discuss its meaning with one another before moving on.

Finally, during the *revised reading* stage, readers shuttle between a close analysis of the text and reflecting on the implications of that text's argument and findings. Some of the strategies that Freedman (2013) describes, such as differentiating between the central argument and the arguments of the sources cited, belong in this stage. This analytical and reflective work is what distinguishes the reading stage from the revised reading stage. Revised reading means that the reader sees the text anew, through new angles and for new purposes. Some of this revision work is local and small, such as noting and analyzing patterns of diction throughout a text's claims and sub-claims. Other revision work is larger and more involved, such as moving on to read a major cited source and then re-reading the original text to understand more fully how the text interpreted and relied on the source. Revised reading also can ask students to make connections across a range of interdisciplinary texts, as described by Kathryn Nantz and William M. Abbott in their chapter in this collection. Nantz and Abbott describe several "brainstormer" assignments they used in their undergraduate Honors course that helped students read economics and history texts for particular purposes (p. 13). The revised reading stage unlocks the quiet, underground moves and implications of a text that may be missed in cursory readings.

Although I make a case in this chapter for teaching students rhetorical reading processes, Huffman's chapter in this collection offers an important caveat about the efficacy of emphasizing rhetorical reading. Huffman collected assessment data over three semesters from students in a newly redesigned developmental reading course at her university. Her study showed that students' reading comprehension did not improve through learning how to rhetorically analyze texts, which includes marking claims, identifying biases, and distinguishing content from purpose. As Huffman explains, the results of her study were surprising to her. She argues that students' continued struggles with comprehension even after being taught how to rhetorically analyze texts may be connected to the kinds of rhetorical reading strategies they were taught and how often these strategies were reviewed. My description of multi-stage readings processes and the reading activities I suggest below are offered with Huffman's findings in mind. Teaching rhetorical reading is not a magic bullet that can solve students' weak reading skills. What is more important is that students are introduced to a wide range of reading processes, that faculty are given adequate support to develop appropriate reading pedagogies for their courses, and that reading itself becomes a frequent and visible component of courses across the disciplines.

Teaching Students Reading Processes in the Sciences

In this section, I describe activities faculty in the sciences can use to teach high school and undergraduate students how to read scientific texts more critically. This section focuses on three commonly assigned genres in high school and undergraduate science courses: 1. the popular science trade book and magazine article; 2. the science textbook; and 3. the empirical research article published in a peer-reviewed journal. The activities I describe guide students towards thinking of reading as a recursive process that includes stages of *pre-reading*, *reading*, and *revised reading*, stages explained in the section above. My recommendations in this section build on Mary Lou Odom's suggestions in her chapter in this collection, in which she advises faculty to carefully consider how they can teach students ways in which students can navigate the complex, often multimodal texts that are assigned in courses across the disciplines.

The examples below derive from my work as a writing program director at both a national military service academy and a regional state college as well as my work as a graduate writing fellow at a large public university. My conversations with my science colleagues at all of these institutions, as well as my discussions about science reading and writing pedagogy with Margaret M.P. Pearce, assistant professor of biology at University of the Sciences, have helped me understand the particular challenges of teaching students how to read popular science trade books, science textbooks, and empirical research articles in ways that will help students more fully understand and participate in scientific discourse communities. Science faculty members, like many faculty across the disciplines, may feel underprepared to teach reading and writing, a worry addressed in writing across the curriculum scholarship (Bean, 2011). Also, many faculty are concerned about the limited class time they have to cover large amounts of content in their courses. Often, teachers worry that spending time in class teaching students specific reading or writing strategies will take too much time away from the course's content (Patton, Krawitz, Libbus, Ryan, & Townsend, 1998). However, I and others argue that integrating assignments that target the development of students' reading processes help students move beyond superficial understanding and engagement with the content they read and learn in lectures and labs (Kalbfleisch, 2016; Morris, 2016).

Teaching students reading processes in their high school and undergraduate science classes can be a way to introduce students to the rhetorical nature of scientific discovery. Including philosopher Thomas Kuhn and rhetoricians Alan G. Gross and Charles Bazerman, scholars who study the rhetoric of science have long argued that scientific writing and scientific research are neither "objective" nor "detached" (Kuhn, 1962; Gross, 1990; Bazerman, 1988). Rather, scientific knowledge is produced through persuasion and shifting social structures and relationships. When scientists write up their findings, or make an argument about a specific hypothesis to a lay but educated audience, they are making claims, not listing facts. Students may not understand the contested, situated nature of scientific texts, and thus may perceive the knowledge presented to them in scientific trade books, textbooks, and empirical research articles as objective truths explained by unbiased writers. Students who hold onto this perspective (seeing science as a disinterested or neutral endeavor) miss out on participating in the scientific process because they do not understand how scientific knowledge is constructed, contested, circulated, and changed over time.

This concept of texts as situated, dynamic arguments is a threshold concept. Threshold concepts are ideas that are fundamental to understanding disciplines and acquiring knowledge. Once someone learns a threshold concept, they do not forget that concept (Adler-Kassner, Majewski & Koshnick, 2012). Although threshold concepts were originally described as tied primarily to disciplinary bodies of knowledge, others, such as the Council of Writing Program Administrators in their WPA Outcomes Statement for First-Year Composition 3.0 (2014) and the Association of College & Research Libraries in its 2015 Framework for Information Literacy in Higher Education, take a more interdisciplinary approach, describing threshold concepts that are shared across disciplines. Because the idea that texts are rhetorically constructed and situated is a threshold concept – not an idea that most students come to the high school or college classroom understanding – reading texts rhetorically is not something faculty should assume their students can master while reading on their own, outside the classroom. Teachers must bring the practice of reading inside the classroom.

Popular Science Trade Books and Magazine Articles: Teaching Reading in a High School Physics Class

One positive outcome of the Common Core State Standards Initiative is its insistence that "reading, writing, speaking, and listening should span the school day from K-12 as integral parts of every subject" ("Key shifts," 2016, para. 13). In other words, English language arts teachers do not bear sole responsibility for teaching students critical literacy skills and practices. Rather, students need to be reading, writing, speaking, and listening in all their content classes, and all K-12 teachers need to teach students how to read, comprehend, interpret, and analyze the complex, content-specific texts they assign in their classes. In grades 6−12, the Common Core State Standards (CCSS) expects that students will be learning how to read informational texts and literary nonfiction in their history, science, and technical classes. These specific "Literacy in History/Social Studies, Science, and Technical Subjects" standards ask teachers to venture beyond the course textbook and ask students to read increasingly complex texts in a range of subject-appropriate genres. The literacy standards expect that students will be able to work with these texts in specific ways, such as being able to name the text's central ideas, figuring out domain-specific vocabulary terms, analyzing a text's structure, and evaluating a text's evidence and conclusions ("English language arts standards," 2016). The CCSS's Appendix B includes a list of grade-specific "text exemplars" that teachers may use in their courses to meet these standards. The informational text exemplars for science, mathematics, and technical subjects at the high school level include government documents (reports from the U.S. Environmental Protection Agency and U.S. Department of Energy), primary texts (Euclid's *Elements*), technical descriptions and definitions that use both text and images, procedures and instruction sets, and various selections from popular science trade books and magazine articles ("Appendix B," 2016).

The CCSS, which have been adopted by 42 states as of July 2016, are not alone in promoting the value of assigning popular science trade books and magazine articles to high school students. The National Science Teacher Association (NSTA) also recommends using high-quality, current science trade books in K-12 science courses and publishes a list of the best science trade books published each year. Trade books, the NSTA argues, can engage students on a deeper level than traditional textbooks: "they pull students into a story-like presentation of scientific information. The topic becomes more real, more understandable, and more personal" (Schlichting, 2002, para. 6). Because many of these texts are written with strong narrative elements (a distinct authorial point of view, a reliance on description, anecdote, and metaphor), they can be more familiar to student and lay audiences. Popular science trade books and magazine articles are also powerfully influential in constructing students' and adults' scientific literacy, or their understanding of scientific and technical topics. In fact, rhetorician Heidi Scott explains how well written popular science trade books can sway the public to subscribe to a scientific theory that is widely contested among professional scientists, such as Stephen Jay Gould's evolutionary theories, just because the arguments are so compellingly written (Scott, 2007).

Even though popular science trade books and magazine articles often have strong narrative elements that make them more "readable" than science textbooks or empirical research articles, students still need to be taught how to read these texts. In other words, popular science trade books and magazine articles require a particular reading process. Below, I describe activities designed to teach high school students a reading process they can use to critically read popular science trade books and magazine articles. I use one of the CCSS text exemplars for grades 11 and 12, Gordon Kane's article, "The Mysteries of Mass," as the basis for these reading process activities. Kane is a leading physicist who studies particle physics and string theory, and his article was published in 2005 in *Scientific American*. Because the reading activities I describe ask students to examine the article's layout and the relationship between the article's visuals and texts, it is important that students read a PDF copy of the original version of the article, with the layout intact.

Kane's article, which would be appropriate for older high school students in a physics class, does more than explain how mass is calculated and the potential impact of the Higgs field and Higgs bosom on scientists' understanding of the nature of the universe. Kane's article demonstrates how a writer takes up a research question and explores that question methodologically through research and descriptions of scientific theories and experiments. What is particularly interesting – and may be perplexing to many high school students – is that Kane does not arrive at an answer to his research question at the end of the essay. His two-part question – "How do elementary particles acquire mass?" and "Why do they have the specific masses that they do?" – is a question that is addressed in part by the theory of the Higgs field, but not entirely (Kane, 2005, p. 34). Kane's research question is genuine: he is explaining to the general, educated audience of *Scientific American* readers the phenomena that his fellow physicists are currently working on and flummoxed by. The uncertainty that Kane admits to emphasizes that science is an open-ended process, with far more questions than conclusive answers. Another reason the Kane article is a good example to use for teaching reading processes is that it is a manageable length for the older high school students: at seven pages long – longer and more sophisticated than the short *Buzzfeed* articles students read, post, and share through social media, yet short enough to read in class. As I argue above, it is essential that students read in class so that the work of reading is made visible in the science classroom. Students need to be taught through modeling, direct instruction, and discussion *how* they should read the texts they are assigned in their science courses.

It is important to interrupt the students' impulse to immediately start reading the article linearly, like they might do with a fictional narrative like a short story. It is also crucial to call students' attention to the fact that this article, like other popular science trade books and magazine articles, does more than define and describe facts. Instead, the writer is making an argument with this article. One *pre-reading* activity that can circumvent both these default instincts is asking students to "map" Kane's article onto the rhetorical triangle. Doing this visual mapping work helps students notice Kane's rhetorical situation: his context, his content, his purpose, and his audience. Teachers can ask students to draw a large triangle surrounded by a circle on a piece of paper, labeling the circle *context* and the three sides of the triangle *audience, content,* and *purpose.* The circle for *context* represents the larger rhetorical situation of the article: who the author is, when the article was written, the larger scientific conversation that this article participates in, and the larger global economic and sociopolitical context. The *content* side of the triangle is concerned with the "what" – the key terms, claims and evidence that the article is discussing. The *audience* side of the triangle addresses "who," both who this article was originally written for and the other stakeholders who are interested in this topic and argument. Finally, the *purpose* side of the triangle tackles the all-important question of "why" – why did the writer write this article, and what is that writer's ultimate objective?

Students can work with each other and the teacher in class to find this information online and within the article. Students can fill the map with words, phrases, bullet points, quotes, dates, and statements that answer these (and other) questions:

- "When did Kane write this? What do you know about what was happening in the world then?
- "Where was this published? What do you know about this publication? What kinds of people might read and subscribe to this magazine?"

- "Who is Gordon Kane? What is he an expert of?"
- "Who is writing to? How do you know?"
- "Who else might be interested in this topic and this article?"
- "Who or what was Kane responding to? How do you know?"
- "What kinds of examples and evidence does Kane use in his essay?"
- "Why, do you think, Kane wrote this article? What is your prediction? How did you make this prediction?"

Mapping this article may take one or two 40-minute class periods, or a full 75-minute block. Every student should have a copy of Kane's article that they can refer to, either printed out or on a tablet or laptop. The teacher can focus the activity by drawing the rhetorical triangle map on the board and filling it in with the students, asking the students to go back to the text and name the sentence, the paragraph, and the page that supports their analysis of Kane's argument and rhetorical situation.

This mapping activity is a powerful in-class *pre-reading* activity for several reasons. First, it compels students to slow down and revisit a text again and again, not to evaluate the evidence or claims but to focus on the text itself. There is a time for evaluation, but it is premature at the *pre-reading* stage – *pre-reading* is about getting a handle on the text and its general scope and trajectory. Second, mapping asks students to read for the general structure of the *argument*, not for content knowledge. The questions above frame the text as piece of responsive discourse, not a collection of statistics, quotes, and points. Third, the activity of drawing and mapping, much like graphic organizers students use in K-12 to plan their writing, makes apparent the kinds of cognitive work expert readers do while reading. As stated above and in this collection's introduction, expert readers are neither linear nor passive readers: they read recursively and with a purpose. By introducing students to mapping early in the course, teachers can come back to this exercise throughout the academic year, asking students to map the texts they read throughout the semester in whole-class discussions, in small groups, with partners, or by themselves.

After this pre-reading exercise, the teacher can ask students to read the article in its entirety. It is important that this reading happens in the classroom, as students need to be able to ask questions, discuss their reading with their teacher and peers, and see their teacher modeling how to read. A helpful classroom activity for the *reading* stage is asking students to write short summaries after they read the article once. Summary writing is a skill that many students lack, as demonstrated in Howard et al.'s 2010 research on student source use. With the Kane article, the teacher can ask students to write a one-sentence summary of Kane's central point, using both his essay and their map of his argument. After students write this one-sentence summary individually, they can write their summary on the board or several large sheets of paper around the room, not labeling their sentence with their name.

These one-sentence summaries will probably be wildly different, as students usually focus on the content the writer is explaining (the definition of the Higgs field or the use of particle accelerators to determine the mass of the Higgs bosom, in the case of Kane's article) rather than the writer's central purpose or argument. When all the one-sentence summaries are displayed, the teacher can lead the class in discussing the similarities and differences among the sentences, noting what key words and concepts are repeated across the summaries.

Although the one-sentence summary activity looks on the surface like a writing activity, I consider it part of the *reading* stage of the reading process I named above. It is another form of active reading or annotation; students shuttle between their *pre-reading* map and the text itself to write the summary. The one-sentence summary activity also illustrates how readers read and interpret texts differently. Each reader's uptake of the text is impacted by his or her own contexts and purposes. For example, students who have a shallow understanding of the physics of atomic structure will read Kane's article differently than students who might have explored topics such as dark energy, cosmology, or the Big Bang on their own. What makes the one-sentence summary activity so powerful is that it helps students distinguish between what the writer is *doing* within the text as a whole versus what the writer is *saying* or *talking about* at any particular place in the text, an important rhetorical distinction explained by Bean (p. 170).

When students read popular science trade books and magazine articles, they usually have an easier time discussing the writer's examples, evidence, and definitions than the writer's central argument. The one-sentence summary activity does not take much class time, yet it invites students to read the article multiple times and begin to notice genre elements. One important genre characteristic of the popular science trade book and magazine article is that the writer's main claim evolves, or becomes more sophisticated, over the course of the argument. A teacher can demonstrate how Kane posits increasingly specific questions over the course of the article by displaying the article on a projector and underlying Kane's claims and inviting students to name how the claims are related to each other. The concept of the evolving thesis is sometimes discussed in writing textbooks (Rosenwasser & Stephen, 2015), yet students often assume texts have the same basic construction as a five paragraph essay: an introduction with the thesis, three points of evidence, and a conclusion that re-states the thesis. A teacher can show students how Kane's central purpose does not appear until the conclusion of his essay: the essay was the work of the argument, not a report of an argument already conceived and settled.

After students read the Kane article and determine its central purpose, one *revised reading* activity they can do is analyze in more depth how the article is organized visually and structurally. In the original version of the article published in *Scientific American*, diagrams, sidebars, and illustrations, which in total constitute about half the length of the seven-page article, surround the main body of the text. Teachers can point to each of these sidebars and diagrams and ask students to discuss or write why Kane might have included each of these elements. What do they *do* for the reader – define a term, give background information, summarize the main points, offer an analogy, illustrate a complex process? This activity can open up a conversation about the interplay between text and image: how does Kane's main text benefit from these visuals? How might the reader's understanding of the scientific concepts he describes in the main text be changed if there were not these sidebars and diagrams?

Another corollary *revised reading* activity that teachers can lead students in doing is asking students to compare and contrast the information they learned in the Kane article with the material they are learning through their textbook and through their hands-on lab work. Compared to course textbooks, popular science trade books and magazine articles like the Kane article are more narrowly focused and often include more detail about specific scientific processes or the history of a scientific discovery. Kane's article on the Higgs field and Higgs bosom explains an active research field awash with different theories about how particles acquire mass and interact with each other. After reading the Kane article in the context of a unit on atomic and subatomic physics, a physics teacher can ask his students these (and other) questions to extend students' reflection and critical thinking:

- How does reading the Kane article change how you understand the material you have been learning in class?
- What information is new to you?
- What is surprising to you?
- Where do you see contradictions? What do you make of these?

Science Textbooks: Teaching Reading in an Undergraduate General Chemistry Course

Research in college-level science pedagogy has shown that textbooks account for at least half of the required reading for undergraduate science courses (Wambach, 1998). Although these texts seem straightforward, students have difficulty engaging with content material from their course textbooks because of weak reading skills, which can be compounded by overall density of science textbooks, the absence of a "story line" to engage students and link facts and chapters together, and science's specialized language and vocabulary (Crow, 2004, para. 6). As Linda Crow argues in her analysis of undergraduate introductory biology textbooks, "biology textbooks are faced with dual purposes of teaching the foreign language of biology with teaching the content of biology" (Crow, 2004, para. 4). Her point resonates with all the sciences, not just biology. High school and undergraduate science students need strategies for navigating their course textbooks because for many students, textbooks are not readily accessible depositories for content. Textbooks also call for a particular reading process.

Content-rich textbooks are not context-free delivers of information. Just like popular science trade books and magazine articles, textbooks are arguments, rhetorically structured for a particular purpose and audience. As researchers in the history of the book and scientific communication have shown, current scientific knowledge and theories are not always accurately and adequately represented in science textbooks. Rather, the science textbooks can be a hub where scientific research, the market, social movements, religious arguments, and government regulations all meet, creating a text which presents a calculated worldview (Shapiro, 2013; Vicedo, 2012, p. 85). Teaching students that the textbooks they read are more than "passive receptacles of the bounties of scientific creativity and research" changes how students read the textbook (Vicedo, 2012, p. 83). Instead of memorizing facts, students can begin to question and critically examine the claims that hide behind the passive voice, nominalizations, and objective tone that characterize science textbooks (Dimopoulus & Karamanidou, 2013). When teachers challenge the textbook's presentation of science as "ahistoric, beyond doubt, universally applied knowledge," they have the potential to not only change how students approach a textbook reading assignment but also how students understand the scientific process (Dimopoulus & Karamanidou, 2013, p. 61).

The activities I describe below can help students read their textbooks more strategically and rhetorically. I use Raymond Chang and Kenneth A. Goldsby's general chemistry textbook, *Chemistry*, as my example text. Published by McGraw Hill, *Chemistry* is now in its 12th edition (2016), and it is a popular and well-regarded textbook used in undergraduate chemistry courses for students who are both chemistry majors and non-majors.

The first thing students probably notice about *Chemistry*, besides its hefty price, is its size. The 12th edition of *Change* and Goldsby's *Chemistry* is nearly 1,200 pages long, divided among 25 chapters, 4 appendices, and copious amounts of front matter and back matter, including a lengthy preface, glossary, answers to chapter questions, and an index. A helpful pre-reading activity early in the course can be to call students' attention to the textbook's rhetorical situation and its organizational principles. Here are questions faculty can ask students to answer as they begin to browse through their textbook:

- When was this published? What does this text's publication date tell you?
- Who are the authors? What do you know about them from the text, and from what you can find through a quick Internet search? How does this information affect how you think about and how you might read this textbook? What stake do they have in this book?
- Glance at the "contents in brief": What are key terms that appear here

among in the chapter titles and subtitles?

- Read through the more detailed "contents": What is repeated in the chapter titles and subtitles in the table of contents? What is missing? What surprises you?
- What are the connections or relationships between the chapter topics? Why might the chapters be organized in this way?
- How might the appendices be useful for you?
- What terms are confusing to you?
- What supplementary materials (digital ebook, animations of chemical processes and reactions) are included, and how do you access them? How might these change how you read this text?
- What do the authors want you (as the student) to learn through this book? What are their priorities? What do they explain as their purpose in their preface?

Many science teachers may already assign students an activity like this; science faculty I've worked with sometimes give students a similar "textbook scavenger hunt" to complete within the first few weeks of the course. However, there is a key difference between that assignment, which is often completed for homework and never talked about in class, and the activity I am suggesting. The above pre-reading activity requires the faculty member to spend time in class discussing what students discovered about their textbook. Again, reading must be brought into the classroom in order for students to learn how to read discipline-specific texts such as their science textbook. The discussion does not have to be long. What is important is that the teacher has a conversation with students early in the course that identifies the course textbook as a rhetorically constructed text, not just a chronicle of facts. When students see the textbook this way, how they read the course textbook can shift: no longer do they merely skim chapters for facts, as novice readers might, but they can also begin questioning, as expert readers do, how the textbook presents scientific knowledge and why it privileges some theories over others.

A reading activity science faculty can do with their students is modeling annotation techniques for textbook reading. In high school, students may have been given study guides, concept maps or other graphic organizers to guide their reading of textbooks (Diep, 2014, para. 5). However, they still may not have an effective reading process for college-level textbooks, a process that helps them focus on the most important information in dense, lengthy textbooks like *Chemistry*. Research has shown that students who annotate while reading their science textbooks have an easier time remembering the information that they read (Zywica & Gomez, 2008). Both faculty and teaching assistants who may lead discussion sections of large introductory science classes can demonstrate how they annotate a textbook by sharing their annotations with their students, either by distributing photocopies of annotated pages, displaying an PDF of annotated pages on an overhead projector or smart board, or simply passing their annotated textbook among a group of students during class. The teacher can suggest a system students can use to either digitally or physically annotate their textbook, such as circling headings and subheadings, highlighting key vocabulary terms, boxing difficult or confusing words, underlying key terms and claims, and writing short notes in the margins about connections between the content on that page and other knowledge they have from other chapters, lab work, or other classes. This modeling activity can be repeated throughout the semester, as even a short five-minute demonstration of a teacher's annotations for a particular chapter can emphasize the importance of annotation. This activity shows students that for expert readers, annotation is an inseparable part of the reading process for reading college-level textbooks, not something done in addition to reading (Zywica & Gomez, 2008, p. 163).

A science textbook's formidable length and dense, informational style can inhibit students from taking the time to re-read and reflect on the theories, knowledge, and arguments the text presents. For instance, an undergraduate student who may or may not be a chemistry major would find it challenging to read and fully digest all 1,200 pages in *Chemistry*, even if that textbook was their primary text in a two-semester introductory chemistry sequence. One revised reading activity that can encourage students to revisit key sections of their textbook is asking students to "translate" a particular passage for a younger high school or middle school audience. This is a variation of the "speaking for science" activity described by Cary Moskovitz and David Kellogg, where students write a press release for a general audience after reading a primary scientific text (Moskovitz & Kellogg, 2005, p. 327). For example, Chapter 2 of *Chemistry*, entitled "Atoms, Molecules, and Ions," gives a historical and theoretical overview of the chemical and physical properties of atoms and elements, explains how elements interact with one another, and describes the organization of the periodic table, molecular models, and chemical formulas.

Within this chapter, which contains eight sub-sections, the textbook authors offer this definition of the term "molecule": "A molecule is an aggregate of at least two atoms in a definite arrangement held together by chemical forces (also called chemical bonds)" (Chang & Goldsby, 2016, p. 50). The paragraph-long definition goes on to state that molecules have a neutral charge and may be formed from atoms of the same element or atoms of two or more elements. This textbook definition contains jargon-laden terms that could be confusing to younger students (e.g. "aggregate" or "definite arrangement.") When undergraduate science students revise this definition of a molecule for a particular audience, such as an eighth grade student, they have the opportunity to see their textbook anew. This revised reading activity invites students to re-read their textbook and use it for a new purpose, as a research source. Through the work of revising this textbook definition, students can think in more depth about the concept of a molecule as well as discuss how different words, shorter sentence lengths, and images might make the concept clearer for younger science students.

Empirical Research Articles: Teaching Reading in an Upper-division Microbiology Course

Recently, scholars of science education have argued for an increased emphasis on reading and discussing primary research in undergraduate courses as a way to introduce students to the values, practices, habits of mind, and discourse of the professional scientific community (van Lacum et al., 2012; Robertson, 2012; Wenk & Tronsky, 2011). Alberts (2009) argued against textbook-centric science teaching, contending that "rather than learning how to think scientifically, students are generally being told about science and asked to remember facts" (para. 1). Textbooks, unlike research articles, are written primarily for students and with the overarching purpose of delivering content. Research articles, on the contrary, are written for scientists in the field. Faculty who want to move away from textbooks in their undergraduate science courses, however, cannot just assign research articles to their students. They must also take the time during class or in small-group discussions and workshops to model a reading process for scientific research articles.

Another advantage of using primary research articles in an undergraduate course such as microbiology is to introduce emerging areas of inquiry that are not yet canonized in scientific texts. One of the recent vigorous developments in microbiology research is the role of gut flora, or gut microbiome, in human health and disease. Drawing on Robertson's (2012) explanation of using journal clubs to teach students reading strategies for scientific articles, below I describe activities to help undergraduate students read a recent study of gut microbiome through stages of *pre-reading, reading,* and *revised reading.* This article, Suez et al's "Artificial Sweeteners Induce Glucose Intolerance by Altering the Gut Microbiota," was published in October 2014 in *Nature,* a top international science research journal.

An important *pre-reading* activity is discussing the purpose and structure of the scientific research article. Understanding the purpose of the genre is part of an expert reader's metatextual awareness (Horning, 2011). The scientific research article is a manifestation of the scientific process: it names (albeit not in this order, which is key to point out to students) the researchers' observations, hypotheses, methods, data, and conclusions. Robertson (2012) suggests creating with students a checklist or worksheet that lists these attributes of the scientific process. Students can then use the checklist as a reading guide. Instead of reading "passively," Robertson argues, the worksheet encourages active, purposeful reading (p. 28). Asking students to bring printed copies of the text or using an overhead projector to display the article is one way to encourage active reading. Having a tangible, visible object to discuss and manipulate helps focus students on the text and facilitates making moves tethered to the text instead of making vague generalizations.

A short but effective *pre-reading* activity for scientific research articles is making predictions for the text based only on the title. Scientific research article titles name the key variables and research findings of a study, and students can be taught to use the titles as summaries to prepare them to read and interpret the study. For example, the title of Suez et al's (2014) study, "Artificial Sweeteners Induce Glucose Intolerance by Altering the Gut Microbiota," gives the reader – even a relatively novice reader – important clues about the study. Faculty can ask students to paraphrase the title, define the key terms in the title (artificial sweeteners, glucose intolerance, gut microbiota), make connections between those terms and their previous experiences and knowledge of microbiology, and predict the methods, assumptions, and possible limitations on the study. A related *pre-reading* activity is previewing the figures, often included in the appendices, and developing interpretations about the study and its findings based on the charts, tables, and figures alone.

Research articles are relatively short (the Suez et al., 2014 study has six pages of text and 11 pages of figures and data), yet they are often densely written with domain-specific vocabulary. In the *reading* stage, it's not necessary to ask students to decode each sentence. Rather, it's more useful to direct students' attention to the most critical parts of the research article for undergraduate students (the abstract, the conclusions, and the discussion) and model how to read. For example, the abstract for the Suez et al. (2014) study is 134 words, thus making it a feasible passage to tackle during class. Faculty can ask students to read the abstract out loud, sentence by sentence, stopping after each sentence to paraphrase, discuss, and look up unfamiliar or confusing terms. Slowing down the reading process within the key sections of a scientific research article, like the abstract, demonstrates to students how sophisticated readers decipher complex texts and how closely texts must be read.

One way to give students contextual awareness (Horning, 2011) for a scientific research article is to introduce them to tracing citations as a method for revised reading (Horning, 2011). Faculty can direct students to the references section of the article, discuss the citation method used in the sciences (Council of Science Editors, or CSE) and its rhetorical implications, and ask students to locate and read another recent article about gut microbiome published from a different lab. This revised reading activity emphasizes the ongoing inquiry work of scientific research: scientists across the world are engaged in similar research, whose relationships can be either cutthroat or collaborative, and they use different methods and variables to solve similar problems. Asking students to compare and contrast two scientific research articles focused on the same general research inquiry sheds light on the dialogic nature of science research and highlights the role of the scientific research article as a mechanism for extending that conversation.

Conclusion

Conversations about student writing issues and/or students' lack of content knowledge at an institutional level need to be reframed and focused on students' reading practices. More often than not, these issues, ranging from shallow understanding of course content to student plagiarism, are symptoms of students' weak reading skills. Confronting these issues without addressing student reading skills is futile as mowing down a lawn full of dandelions. The dandelions – and the problems that emerges from weak reading skills – will keep popping up. In order to help students become better readers of the complex texts faculty across the disciplines assign, faculty need to model the reading processes for expert readers use and design in-class activities that can help students acquire these processes.

The three examples of reading process pedagogy that I described above illustrate a few strategies high school and college science faculty can use to help their students read three discipline-specific genres: the popular science trade book and magazine article, the science textbook, and the empirical research article. Through these examples, I hope to give science teachers an adaptable model for how they can talk with their students about what it means to read these genres, how they can demonstrate the reading processes of skilled readers, and how they can support their students' emerging reading processes. One benefit of teaching reading in science courses is that it gives faculty an opportunity to teach students the dynamic, rhetorical nature of science texts. Faculty in other disciplines can modify these particular pre-reading, reading, and revised reading activities for other subjects, genres, and levels of students. Through these activities, students can begin to imitate the recursive processes expert, college-level readers use as they decode and analyze texts.

All high school and college faculty need to reframe how we think about reading. Reading is far from a basic skill mastered in elementary school or in a first-year writing class. Reading processes students learn in other classes, grades, and contexts are not easily transferrable. This problem of transfer has been discussed in writing studies research (Carillo, 2015), and Chris Anson's study of how even expert writers struggle to transfer their writing knowledge and writing skills should give pause to faculty and administrators who may claim that students should "already know how to read" (Anson, 2016). Even when a student is a good reader in one class or one context, that does not necessarily guarantee that he or she will read well or read critically in another class or context. Every text is different, and so teachers need to continually model and talk about how to read the genres in their discipline. Although faculty members are often expert readers, they might not be experienced at teaching students how to interact critically with texts. In order to help students acquire college-level reading skills through the stages of pre-reading, reading, and revised reading, faculty need to be supported by their institutions as they develop ways to teach discipline-specific reading strategies. It will take time for students to learn how to read, and it will take time for faculty across the disciplines to learn how to teach reading. Yet, this investment of time and energy is worth it. Just as teaching writing across the curriculum helps students learn the values and practices of specific disciplines, teaching reading across the curriculum can also help students understand and participate in the disciplines they are studying.

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