Analyzing the Vocabulary Demands of Introductory College Textbooks

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Abstract

This article describes a study designed to compare the vocabulary demands of introductory college textbooks in several disciplines. The results suggest that the new-vocabulary load in biology textbooks is not as high as that in foreign-language textbooks – as has often been reported – but is higher than in other disciplines. The article concludes with suggestions for helping students manage the vocabulary demands of introductory courses across the curriculum.

Key words: *Science vocabulary; college textbooks; teaching methods; student learning.*

There is a widely reported claim about biology textbooks that goes something like this: Students encounter more new terms in an introductory biology textbook than in a foreign-language textbook. Most recently, I found the claim in a book about "threshold concepts" – those key concepts that a student must understand before advancing in a discipline:

> **Passage 1, from a Biology Professor (Taylor, 2006)**
> Did you know that there are more new words in a first year university biology textbook than in a university first year French book?

Variations of this claim have appeared in many sources, including within my own discipline, rhetoric and composition. Passage 2, for example, is from a book about writing across the curriculum:

> **Passage 2, from an Education Professor (Langer, 1992)**
> The typical biology course requires students to master several times as many new words as they would learn if they were studying a totally new language.

This article describes a study designed to compare the vocabulary demands of introductory college textbooks in several disciplines.

A Google search produces more than a dozen similar claims about biology textbooks. Passages 3 and 4 are examples. No source citation followed either statement.

> **Passage 3, from a College Administrator (Goroff, 2000)**
> Learning a science is like learning to speak a foreign language; studies show that typical biology textbooks introduce students to even more new vocabulary than foreign-language textbooks do!

> **Passage 4, from a Botany Professor and a Genetics Professor (Armstrong & Collier, 1990)**
> Introductory biology textbooks average 738 pages long and present over 3500 new terms, which is around 45–50% more new words than are presented in a semester of foreign language!

The claim is often repeated; I've repeated it myself. But on what evidence is it based?

In this article, I summarize what previous research shows and offer data-driven answers to two questions: (1) Do introductory biology textbooks include more new terms than introductory foreign-language textbooks? (2) Do biology textbooks include more new terms than textbooks in other (non-foreign-language) disciplines? I also discuss ways to help students meet the vocabulary demands of introductory courses.

○ Previous Research

As easy as it is to find the claim, it's more difficult to find evidence that there are more new terms in a biology textbook than in a foreign-language textbook. What research there is focuses on K–12 science textbooks. Yager (1983)

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and Groves (1995) each analyzed pre-college-level science textbooks and concluded that chemistry – not biology – has the highest vocabulary demand.

Yager (1983)

In 1983, Robert Yager estimated the number of "special/technical" words in K–12 science textbooks. Three high school biology textbooks, two high school chemistry textbooks, and two high school physics textbooks were included in the sample. Yager asked a team of five graduate students (from nonscience disciplines) to count the "specialized/technical" words on every tenth page. If figures dominated a given tenth page, the readers analyzed the next full page of text. Yager does not indicate how the readers determined that a word was "specialized" or "technical." After determining from this subsample the average number of new terms per page, Yager estimated the number of new terms per book. He concluded that chemistry books had the highest occurrence of new terms (averaging 18 terms per page), higher than both biology (16 terms per page) and physics (12 terms per page).

Yager acknowledged problems with his methods. First, when determining the average number of *terms* per page, Yager analyzed only full pages of text; yet when determining the number of *pages* per book, he counted all pages. For example, in the case of one biology textbook, Yager multiplied the average number of new terms per page (10.9) by the number of physical pages (912) to arrive at the estimate of 9941 new terms in the book. Because figures are common in science texts, Yager's page counts are exaggerated, as is the estimated number of terms. Second, if a specialized term appeared twice, Yager counted it twice, further inflating the totals.

Yager didn't actually analyze any foreign-language textbooks but instead cited *recommended* caps for the number of words French students learn in a year (2500 for high school and 3000–3500 for college). Despite the methodology problems, Yager concluded that "typical science teaching does require students to master more new words than would be typically required in studying a totally new language" (p. 584).

Groves (1995)

In 1995, Fred Groves reexamined one biology book, one chemistry book, and one physics book from Yager's sample of high school textbooks, but he counted new terms on every fifth page (rather than every tenth), counted repeated terms only once, and counted pages with less than a half page of text as one-half rather than whole pages. As a result, Groves's totals, though still estimates, are more accurate than Yager's. A comparison of their results for chemistry and biology textbooks appears in Table 1. Groves concluded that Yager's claim that students learn more new words in a science course than in a foreign-language course should be "modified" (p. 233). However, like Yager, Groves analyzed no foreign-language textbooks.

○ Research Questions

Neither Yager nor Groves tested whether the number of new terms in *college* biology textbooks exceeds that of college foreign-language textbooks, as is so often claimed. In this study, I counted the new terms in college-level textbooks: two for biology, two for French, and two for Spanish. I also counted the new terms in textbooks from four other (non-foreign-language) disciplines to determine whether the new-vocabulary demands in biology are any higher than in other disciplines.

Specifically, I address these questions:

1. How many new terms appear in biology textbooks compared to French and Spanish textbooks?
2. How does the new-vocabulary load of biology textbooks compare to that of accounting, art history, chemistry, and computer-programming textbooks?

○ Methods

To learn how the new-vocabulary demands in a biology course compare to those in foreign-language courses, I analyzed introductory college textbooks for biology, French, and Spanish. I also analyzed chemistry textbooks because both Yager (1983) and Groves (1995) found that high school chemistry textbooks include even more new terms than biology textbooks. Finally, I analyzed textbooks for accounting, art history, and computer programming. Like science and foreign language, these subjects have heavy vocabulary demands and are often taught in sequence courses that use a single textbook for an entire academic year.

For each discipline, I analyzed the textbook used at my college and one other textbook considered by a professor in the discipline to be a typical introductory textbook. For accounting, art history, biology, chemistry, French, and Spanish, the two books for each discipline are similar in content and organization. The two computer-programming textbooks, however, are not equivalent in purpose (one is a general introduction to the discipline and the other

Table 1. Comparison of Yager's (1983) and Groves's (1995) results.

High School Textbooks	Estimated Number of New Terms per Page	Estimated Number of New Terms per Book
Chemistry		
Yager (average of 2 books) Groves (1 book)	18.2 5.75	12,769 2950
Biology		
Yager (average of 3 books) Groves (1 book)	16.4 4.69	12,560 1899

teaches a specific programming language), but both books are used in introductory courses at my college. Textbook titles appear in the Appendix.

In the non-foreign-language textbooks, a term was counted as a "new term" if it appeared in bold type and was defined for the reader in the running narrative of the text. I counted the bolded new terms on each page of the accounting, biology, chemistry, and computer-programming books. I also did this for one art history textbook. For the other art history book, I counted glossary terms because new terms in that book did not appear in bold type. Terms appearing in figures (for example, lists of chemical elements) were not counted, unless the terms also appeared in bold within running narrative. Terms bolded more than once were counted only once. In the French and Spanish textbooks, I counted words in the end-of-book dictionaries. A chapter number followed each word in the dictionary, indicating that the word also appeared in the text.

Plurals were not considered new terms. Similarly, masculine and feminine forms of a noun (e.g., French *principal* and *principale*) were counted as a single word. However, in all disciplines, the adjective and noun forms of words (e.g., *ecology* and *ecological*) were counted separately.

In the French and Spanish textbooks, expressions (like French *pas du tout*) were counted as single terms, as were verbs. I counted a verb more than once only when the verb is so "irregular" it is unrecognizable in its various forms. For example, forms of the French verb *être* (to be) were counted separately (*je suis*; *tu es*; *il/elle est*; *on est*; *nous sommes*; *vous êtes*; *ils/ells sont*).

A page with *more* than one-half page of exposition was counted as a full page of text, and a page with one-half page of exposition or less as one-half page. This likely resulted in an underestimate of the number of new terms per page. In the non-foreign-language textbooks, pages devoted to program code, problems, equations, tables, images, and appendixes were not counted. In addition, pages devoted to review were not counted because in most textbooks reviews are unlikely to introduce new terms. However, in the French and Spanish textbooks, pages devoted to activities and practice were counted because they make up the majority of pages in a foreign-language textbook. In the accounting textbooks, particularly, pages devoted to tables, figures, and numbers exceed pages of narrative text (Table 2).

Using the estimated number of pages of text (excluding figures, tables, etc.) and the total number of specialized terms, I estimated the number of new terms per page of full text for each non-foreign-language book.

○ Results

Table 3 shows the results for the first research question: How many new terms appear in the biology textbooks compared to the French and Spanish textbooks? In the biology textbooks, the number of new terms does not exceed the number of new terms in the foreign-language textbooks.

Table 4 shows the results for the second research question: How does the new-vocabulary load of biology textbooks compare to that of accounting, art history, chemistry, and computer-programming textbooks? Both the number of new terms and their rate of occurrence are higher in the biology textbooks than in the other non-foreign-language textbooks.

The disparity in the rate of new terms in the two computer science books can be explained by their difference in purpose. One book (Evans et al.) is an introduction to the discipline, explaining a variety of new technology trends. The other book (Reges & Stepp) teaches how to use a specific programming language (JAVA). It features fewer new terms in part because many pages are devoted to program code and problems. It should also be noted that the two biology books, although introductory-level,

Table 2. Numbers of pages analyzed (actual and adjusted).

Books	Number of Physical Pages, Excluding Front & End Matter	Estimated Number of Pages of Text, Excluding Figures, Tables, etc.
Biology		
Hillis et al.	909	573
Reece et al.	1261	785
Chemistry		
Bettelheim et al.	758	364
Stoker	982	475
Computer Programming		
Evans et al.	465	311
Reges & Stepp	1092	855
Accounting		
Pollard et al.	1163	344
Weygandt et al.	1189	376
Art History		
Honour & Fleming	935	629
Stokstad & Cothren	1136	552

Table 3. Numbers of new terms in biology and foreign-language textbooks.

Books	Estimated Number of Pages of Text, Excluding Figures, Tables, etc.	Number of New Terms
Biology		
Hillis et al.	573	1694[a]
Reece et al.	785	1899[a]
French		
Mitschke et al.	465	2584[b]
Pons et al.	289	3190[b]
Spanish		
Blanco & Donley	557	2422[b]
de Castells et al.	474	2015[b]

[a] Terms bolded in text.
[b] Terms in end-of-book dictionary.

Table 4. Numbers of new terms in non-foreign-language textbooks.

Books	Estimated Number of Pages of Text, Excluding Figures, Tables, etc.	Number of New Terms	Estimated Number of New Terms per Full Page of Text
Biology			
Hillis et al.	573	1694	2.96
Reece et al.	785	1899	2.42
Chemistry			
Bettelheim et al.	364	766	2.10
Stoker	475	646	1.36
Computer Programming			
Evans et al.	311	525	1.69
Reges & Stepp	855	315	0.37
Accounting			
Pollard et al.	344	493	1.43
Weygandt et al.	376	494	1.31
Art History			
Honour & Fleming	629	559	0.89
Stokstad & Cothren	552	527	0.95

are intended for potential science majors, while the chemistry textbooks are more general introductory texts. It's possible that other introductory biology textbooks include fewer specialized terms.

○ Discussion

In 1983, Yager wrote that science courses "require students to master more new words than would be typically required in studying a totally new language" (p. 584). His claim is based on an analysis of seven high school science textbooks and no foreign-language textbooks, and his methods likely produced exaggerated estimates. Nonetheless, Yager's statement appears to be the basis of the oft-repeated claim that *college biology* textbooks include more new terms than foreign-language textbooks. That is not the case in the two biology books and four foreign-language books I examined.

More importantly, it's difficult to compare the vocabulary demands of one discipline to those of another. Certainly, a tally of new words underestimates the challenge of learning a foreign language. When I asked foreign-language professors at my college about the vocabulary demands in their courses, they noted that foreign-language students don't just learn new words; they learn verb conjugations, new pronunciations, new spellings, and grammar peculiarities. They must learn connotations, collocations, and grammatical gender of words, as well as cultural and regional variations. Idiomatic phrases pose yet another challenge. In French, for instance, key verbs (*être*, *avoir*, *aller*, *faire*) in many expressions are not literally translated. Students struggle to understand "illogical" instances like these, notes Spanish professor Antonio Cruz, and their frequency only increases as students advance (e-mail message to author, March 22, 2015).

Science students struggle with vocabulary for different reasons. Here, for example, is a paragraph about fungi from a biology textbook. Although the paragraph includes no bold (new) terms, students have only recently been introduced to the underlined terms:

> The zygospore fungi include four major lineages of terrestrial fungi that live on soil as saprobes, as parasites of insects and spiders, or as mutualists of other fungi and invertebrate animals. They produce no cells with flagella, and only one diploid cell – the zygospore – appears in the entire life cycle. Their hyphae are coenocytic. Most species do not form a fleshy fruiting structure; rather, the hyphae spread in a radial pattern from the spore, with occasional stalked sporangiophores reaching up into the air. (Hillis et al., 2012, p. 448, emphasis added)

Reading is usually perceived as difficult when 2% or more of the words are unknown (Carver, 1994). In the above passage, 21% of the words are relatively new for most students, and the terms themselves refer to new concepts. When French professor Arienne Arnold asked her students whether learning science or French vocabulary is more difficult, they noted that in French, words refer to familiar concepts: "*Une chaise* is a chair, and you can remember that by putting a sticky note on a chair that has the French word on it." Even for abstract words like "revolution," a word with similar meaning exists in the student's native language (e-mail message to author, March 17, 2015). Conversely, many terms in the sciences are invented to identify concepts for which the common language has no existing terms. In addition, many science words denote substances, concepts, or processes too abstract to be directly experienced and too foreign to be explained with analogy. Even understanding their definitions requires knowing a good deal of science vocabulary (Snow, 2010). As a result, learning a hundred "new" terms in a foreign-language course is not the same as learning a hundred new terms in a science course.

Abbreviations, symbols, and formulas add to the vocabulary load in science courses, and science vocabularies continue to grow to accommodate new knowledge. According to biology professor Linda Crow (2004), "In just 20 years, the number of chapters in an introductory biology college text has doubled." While discussing the single field of signal transduction, Donald Kennedy (2002), former editor-in-chief of *Science Magazine*, noted that the "growing alphabet soup of acronyms" makes it difficult for even discipline insiders to deal with the "information overload" (p. 1569).

The vocabulary load for students taking science courses is high; the demands on students who take additional courses at the same time are even greater. In art history, for instance, students memorize hundreds of titles, along with the style, artist, and medium or material of each work (T. Walker, e-mail message to author, March 31, 2015). In accounting, students must learn new definitions for familiar words like *capital*, *cash*, *cost*, *debit*, *depreciation*, and *profit* (T. Wend, e-mail message to author, April 8, 2015). In this situation, students can struggle with remembering the new, discipline-specific meanings of words (Rodd et al., 2012).

Reading texts loaded with new vocabulary can leave students with little "cognitive energy" for thinking about the concepts (Francis & Simpson, 2009, p. 97). For faculty, then, the question of which discipline has more new vocabulary is not as important as a question like "How much specialized vocabulary do students need in order to understand the concepts in introductory courses?" A growing body of evidence suggests it may not be as much as we think. In one introductory biology course intended for potential science majors, for example, Barsoum et al. (2013) piloted a textbook that emphasizes application of concepts over memorization of vocabulary. They found that students using the piloted textbook, despite learning fewer terms, learned as much factual knowledge, retained that knowledge longer, and demonstrated more accurate understanding of the discipline than students in control groups. McDonnell et al. (2016) asked students in an introductory cell biology course to read jargon-free explanations of genome content and DNA structure *before* being introduced to the technical terms in class. Students in a control group read a more traditional text (prelecture) that both explained the concepts and introduced the technical terms. On a posttest, the groups performed similarly on multiple-choice questions. However, compared to students in the control group, students who read the plain-language explanation (before being introduced to the technical terms) provided 1.5 times more correct responses to open-ended questions about the genone and 2.5 times more correct responses to questions about DNA structure. The authors theorize that the cognitive demands of learning new concepts and vocabulary at the same time may impede learning. Others have documented the benefits of using "plain English" to introduce concepts in science courses (Li et al., 2014; Schoerning, 2014) as well as computer-science courses (Neeman et al., 2008).

The following techniques can help students master the vocabulary that is essential in our fields.

Raise Vocabulary Awareness

Helping students recognize and decode new vocabulary in their reading can improve their comprehension. Harmon and Pegg (2012) found that college students who completed literacy activities in their biology labs demonstrated higher gains on a posttest than students in the control group. Students in the treatment group were also less likely to drop the course. One activity Harmon and Pegg recommend is teaching students to break up a new technical term by considering its prefix, suffix, and word root.

Repeat, Repeat, Repeat

Students need to encounter a new term from five to as many as 20 times before mastering it (Waring & Nation, 2004). Spacing those encounters in intervals of increasing length fosters long-term learning. Long-term learning is also fostered when retrieving information from memory requires effort (Brown et al., 2014). Encourage students, for example, to review new vocabulary without the definitions being immediately visible. Encountering new terms in different contexts also appears to promote learning (Nation, 1990; Francis & Simpson, 2009).

Make Connections

To aid memorization, help students find connections. One technique is word-sorting activities. Students in groups are given new terms written on slips of paper and asked to organize them into categories using only their intuition, prior knowledge, and knowledge of word roots, prefixes, and suffixes. Then, after reading an assignment that includes the new terms, students revise their original categorization system (Nixon & Fishback, 2009). Francis and Simpson (2003) suggest an exclusion exercise. Students select from groups of words the word that doesn't relate to the others and then identify what connects the remaining words.

Teaching related words together encourages "semantic mapping" (Bravo & Cervetti, 2008, p. 138) and allows students to draw upon their prior knowledge. A different way to encourage "semantic mapping" is to draw attention to how the discipline-specific meaning of a word (such as "variable," "dependent," "normal," and "significant" in statistics) is semantically related to the meaning students already know (Rodd et al., 2012).

Provide Visual Aids

Images can reinforce the meaning of new words because students encode the information in two different ways (Chun & Plass, 1996). In one study by Cohen (2012), students who drew an image of the new term they were learning demonstrated an even higher rate of short-term recall than students who viewed a picture of the new concept.

Read

Reading may be less efficient than direct instruction for learning vocabulary, but through reading students gain both knowledge of definitions and knowledge of the various ways words can be used (Pigada & Schmitt, 2006). In addition, students who are taught to read their textbooks actively are more likely to retain the information (Simpson & Nist, 1990; Huffman-Kelley et al., 2015).

Practice Using Words

An extensive body of research has demonstrated the benefits of "active learning" methods that get students to experiment with, think about, and practice using new words (Francis & Simpson, 2009; Freeman et al., 2014). For example, Hohenshell et al. (2013) describe a "choral repetition" technique used in an animal physiology course. After hearing the instructor say the new word, students repeat the word several times. Students reported that hearing new terms and repeating them aloud helped them notice the terms in their reading and remember the terms. May et al. (2013) describe similar benefits for their "biological dialogues" assignment. After receiving 25–30 new terms, pairs of students compose (outside of class) a written dialogue that integrates all the terms. Some or all of the dialogues are then "performed" in class. The repetition, along with hearing the terms used in dialogue, reinforces students' knowledge of both the meaning and usage of new terms. Other write-to-learn activities, such as having students explain new concepts in lay terms, can reveal to both student and instructor the level of understanding. (For writing activities, visit Colorado State University's writing-across-the-curriculum website at http://wac.colostate.edu/intro/pop2d.cfm.) The combination of passive techniques (reading and listening) and active techniques (speaking and writing) reinforces learning and promotes understanding.

○ Conclusion

Most of us consider learning disciplinary vocabulary to be essential to learning disciplinary concepts. However, we likely underestimate how frequently students encounter unfamiliar words in their introductory courses. Being mindful of these vocabulary demands when selecting reading material and when introducing new terms can help students learn both the concepts and the languages of our disciplines.

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Appendix: List of College Textbooks Analyzed

Bettelheim, F.A., Brown, W.H. & March, J. (2004). *Introduction to General, Organic, and Biochemistry, 7th Ed*. Belmont, CA: Brooks/Cole-Thomson Learning.

Blanco, J.A. & Donley, P.R. (2012). *Vistas: Introducción a la Lengua Española, 4th Ed*. Boston, MA: Vista.

de Castells, M.O., Guzmán, E.E., Lapuerta, P. & Liskin-Gasparro, J.E. (2015). *Mosaicos: Spanish as a World Language*. Boston, MA: Pearson.

Evans, A., Martin, K. & Poatsy, M.A. (2012). *Introductory Technology in Action, 9th Ed*. Boston, MA: Pearson.

Hillis, D.M., Sadava, D., Heller, H.C. & Price, M.V. (2012). *Principles of Life*. Sunderland, MA: Sinauer Associates.

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Pollard, M., Mills, S.K. & Harrison, W.T., Jr. (2007). *Principles of Accounting*. Upper Saddle River, NJ: Pearson Education.

Pons, C., Scullen, M.E. & Valdman, A. (2009). *Points de Depart*. Upper Saddle River, NJ: Prentice Hall.

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