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A Corpus-driven Approach toward Teaching Vocabulary and Reading to English Language Learners in U.S.-based K-12 Context through a Mobile App

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A CORPUS-DRIVEN APPROACH TOWARD TEACHING VOCABULARY AND READING TO ENGLISH LANGUAGE LEARNERS IN U.S.-BASED K-12 CONTEXT THROUGH A MOBILE APP

A dissertation submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

CURRICULUM & INSTRUCTION

by

Seyedjafar Ehsanzadehsorati

2018
To: Dean Michael R. Heithaus  
   College of Arts, Science and Education  

This dissertation, written by Seyedjafar Ehsanzadehsorati, and entitled A Corpus-driven Approach toward Teaching Vocabulary and Reading to English Language Learners in U.S.-based K-12 Context through a Mobile App, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this dissertation and recommend that it be approved.

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Florida International University, 2018
DEDICATION

I dedicate this dissertation to my mother, Leila, لیلا
ACKNOWLEDGMENTS

I would like to give my endless thanks to my supervisor, Eric S. Dwyer, who taught me how to write a dissertation. He has given me huge support over the past four years of my PhD and I am greatly indebted to him, thank you.
ABSTRACT OF THE DISSERTATION

A CORPUS-DRIVEN APPROACH TOWARD TEACHING VOCABULARY AND READING TO ENGLISH LANGUAGE LEARNERS IN U.S.-BASED K-12 CONTEXT THROUGH A MOBILE APP

by

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Florida International University, 2018

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In order to decrease teachers’ decisions of which vocabulary the focus of the instruction should be upon, a recent line of research argues that pedagogically-prepared word lists may offer the most efficient order of learning vocabulary with an optimized context for instruction in each of four K-12 content areas (math, science, social studies, and language arts) through providing English Language Learners (ELLs) with the most frequent words in each area. Educators and school experts have acknowledged the need for developing new materials, including computerized enhanced texts and effective strategies aimed at improving ELLs’ mastery of academic and STEM-related lexicon.

Not all words in a language are equal in their role in comprehending the language and expressing ideas or thoughts. For this study, I used a corpus-driven approach which is operationalized by applying a text analysis method. For the purpose of this research study, I made two corpora, Teacher’s U.S. Corpus (TUSC) and Science and Math Academic Corpus for Kids (SMACK) with a focus on word lemma rather than inflectional and derivational variants of word families. To create the corpora, I collected and analyzed a
total of 122 textbooks used commonly in the states of Florida and California. Recruiting, scanning and converting of textbooks had been carried out over a period of more than two years from October 2014 to March 2017. In total, this school corpus contains 10,519,639 running words and 16,344 lemmas saved in 16,315 word document pages.

From the corpora, I developed six word lists, namely three frequency-based word lists (high-, mid-, and low-frequency), academic and STEM-related word lists, and essential word list (EWL). I then applied the word lists as the database and developed a mobile app, Vocabulary in Reading Study – VIRS, (available on App Store, Android and Google Play) alongside a website (www.myvirs.com). Also, I developed a new K-12 dictionary which targets the vocabulary needs of ELLs in K-12 context. This is a frequency-based dictionary which categorizes words into three groups of high, medium and low frequency words as well as two separate sections for academic and STEM words. The dictionary has 16,500 lemmas with derivational and inflectional forms.
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Definitions of key terms

For this dissertation, the following definitions are put forward:

Academic vocabulary: Are words that appear constantly across all four content areas, math, language arts, science, and social studies. Academic words are also words whose meaning often change across different subject matters (Baumann & Graves, 2010).

Corpus: A large body of written or spoken natural language which is analyzed via computer-assisted programs (Stubbs & Halbe, 2013).

Corpus-based research: The goal here is to investigate the systematic patterns that governs the linguistic features. This method of research is a top-down approach in which grammatical features are described (Biber, 2012).

Corpus-driven research: Corpus-driven analysis uses the unique features of a text to determine linguistic categories. Therefore, all linguistic categories are systematically derived from frequency distributions (Tognini-Bonelli, 2001).

Elaboration: Elaboration enhances encoding processes in WM through linking a new item to the conceptually related schemata in LTM. Elaboration improves word retrieval through linking a new word to the network of active vocabulary knowledge (Schunk, 2012).

Incidental learning: Incidental L2 learning is defined as learning that takes place without either intentionality or awareness. The line of research on incidental learning argues that L2 vocabulary learning does occur through reading (Chen & Truscott, 2010).

Intentional learning: Ellis (1994) argues that intentional learning requires focal attention to be placed on linguistic form. Intentional learning is directly focusing on the learning item.

Learning burden: Is defined as the amount of effort that a learner usually puts to learn a word (Nation, 2016).

Lemma: Is the school dictionary that comes with some but not all the derivational and inflectional forms; however, word family has all the forms.

Retrieval: The ability to use the learned materials in everyday conversation. Retrieval is different from learning (Schunk, 2012).

Threshold level: A minimum amount of vocabulary knowledge that marks the boundary for gaining a successful comprehension (Nation, 2001).
Text coverage: Is the number of words that the target students at a particular level of proficiency know. Nation (2013) claims that students should know every eight out of ten words in a text to be able to reach a successful reading comprehension.
CHAPTER I
Introduction

K 12 textbooks critique

Imagine a kindergarten class where a new immigrant child has to study phonics, a lesson plan requiring students to learn swatches of words that rhyme. The initial assumption for most teachers is that children know the words. English Language Learners (ELLs), however, do not necessarily know these words. Here, not only do teachers then foist new language upon them; they pound them with words that all sound alike (Wyse & Goswami, 2008), asking them to parse among them without assistance.

In a traditional teaching sequence, a lesson or chapter starts with new words and ends with vocabulary as a reference (Jameson, 2012). The reading passage is the first step that students are required to read followed by study questions and discussion materials. *Florida Reading/Writing for Grades 4-5* (p. 69) is a good example of such a teaching sequence. The sequence is difficult for ELLs because they do not have the required cultural or even background knowledge needed for understanding the reading material; meanwhile, this method of presenting the content is in contrast with Krashen’s (1989) ‘i + 1’ that claims that input should be a little higher than the current proficiency level of the learners. However, this teaching sequence seems to be ‘i + many’ for ELLs. According to Center of Applied Linguistics (Jameson, 2012), a possible answer to the above-mentioned problem is to Teach-the-Text-Backward in which teachers are recommended to first discuss the material in class in order to activate the ELLs’ schemata. Study questions should be
answered following the discussions and finally reading the text should be the last part of the class instruction.

**Lexicon in a second language in K-12 context**

Lexicon is one of the key building blocks in learning a language. The path toward vocabulary development in a second language (L2) takes time and requires enormous effort. To many language learners, vocabulary learning may seem endless, as they encounter new unknown words every day.

Moreover, many words that ELLs encounter in school are less common words that represent rare elements of a child’s home life, but they may still only be selectively pertinent words to very specific situations that put further challenges in front of the ELL’s learning path (Townsend and Collins 2009). The above-mentioned scenario seems to worsen as language learners, including EFL and international students, move toward advanced level of language proficiency.

**Context of K-12 vocabulary learning in a second language**

It is generally agreed that ELLs need more than five years, at least, to gain a fair command of academic English (Cummins, 1981; Hakuta, Butler, & Witt, 2000). Since ELLs may have less experience with English language, as well as a lack of receiving proper academic English prior to their matriculation in mainstream classes, they could face additional challenges in the K-12 context compared to their peers who speak English as their first language.
Unlike ELLs’ orthographic knowledge in the L2 that apparently develops like native speaker's (Chiappe, Siegel, & Wade-Woolley, 2002), Bialystok, Luk, and Kwan (2005) claim that young foreign language learners’ semantic proficiency is far behind native speakers at the same age in K-12 setting. Since the ELLs’ dual task of learning content area subjects while developing their language proficiency can be such a huge task, doing so may cause ELLs to score below state average on key standardized tests (Bialystok, et al., 2005). According to the Institute of Education Sciences (2007), ELLs’ grades fourth, eighth, and twelfth in 2013 were constantly below the mean scores for the age groups. The gap that I explained here, as a result, yields to a higher rate of drop-out of ELLs and students from minority backgrounds (Snow & Biancarosa, 2003).

In the same vein, the Sheltered Instruction Observation Protocol (SIOP) (2018), a commonly implemented instruction model for K-12, has repeatedly claimed the eminent need of academic language for K-12 ELLs and has practically shown the significance of addressing such a need in helping ELLs to move effectively toward their school success. SIOP workshop leader, Lydia Stack, (personal communication with Eric Dwyer, November 2017) reports that teachers regularly ask her what academic language is and what content and language objectives are. In other words, many teachers may feel insecure in their ability to select appropriate vocabulary on their own.

---
1-see Chapter 2 for a detailed description of lemma
2-the supervisor of this dissertation
3-gap refers to systematic difference between two entities including cultures or languages
Academic vocabulary

Since, one’s academic prowess in English language discourse (à la Cummins, 1981, and Cook, 1989) seemingly is the crux of success with ELLs, academic vocabulary may be presumed to be an integral part of academic language, a register on its own which seemingly are the foundation of academic materials (Nation & Kyongho, 1995; Scarcella, 2003). Academic words tend to be non-concrete words, low in frequency, carrying a semantically opaque nature that inadvertently pose a comprehension challenge for ELLs (Corson, 1997). More importantly, though, students’ challenge with academic vocabulary appears to be one of input: Students tend only to encounter such language through texts—not everyday conversation or even public media. Thus, even mainstream students with good conversational skills who lack enough exposure to academic texts need the sources for improving academic vocabulary.

General academic vocabulary (known as academic vocabulary in this study) refers to the category of words that appear in a wider range of disciplines or subject matter. Townsend (2009) defined academic vocabulary as words that are a serious challenge for learners to master because they have abstract definitions. Hiebert and Lubliner (2008), however, focused on the semantic aspect of general academic vocabulary, defining it as words whose meanings regularly change across different subject matters. Textbook writers and teachers assume that ELLs notice this meaning change and know different meanings across content areas (Townsend & Collins, 2009; Vacca & Vacca, 1996), however, most ELLs fail to notice. In her study, Coxhead (2000, p. 218) defines academic vocabulary as
words—e.g., estimates, overestimate, and underestimate—that uniformly occur in several academic subjects.

**STEM-related vocabulary**

For many outsiders—and even K-12 teachers—the difference between academic vocabulary and STEM-related words is confusing. Marzano and Pickering (2005) used domain-specific academic vocabulary to refer to STEM-related words. They believe that it is the most common kind of academic vocabulary that appears in academic settings. They suggest that direct teaching of STEM-related vocabulary is the most appropriate classroom teaching activity that a teacher could apply to make sure that students, including ELLs, have the required academic knowledge to grasp the subject matter they encounter through school textbooks (p. 1). *Central tendency, mode, median, and range* are examples of domain-specific academic words used in the subject matter of statistics.

However, Fisher and Frey (2008) use the term *technical vocabulary* to refer to these words; meanwhile, *content-specific vocabulary* is the term Hiebert and Lubliner (2008) use in referring to STEM-related vocabulary. In Figure 1, an academic vocabulary classification system for the present study is presented. As seen in the figure, the classification is founded on two criteria: meaning and frequency. Semantic aspects of words are applied to determine academic and STEM-related vocabulary; however, the frequency criterion is used to categorize words into three levels of high, mid, and low frequency.
Figure 1. Academic vocabulary classification system.

Academic vocabulary classification system for this study

- Hiebert and Lubliner (2008)
- Harmon, Wood, & Hedrick
- Fisher and Frey (2008)
- Tom Cobb (2018)

1. High Freq.
2. Medium Freq.
3. Low freq.
Fundamental issues with respect to vocabulary teaching and learning

Teachers are under heavy pressure to cover all the materials in textbooks during a limited amount of time over the school year (Snow & Biancarosa, 2003; Townsend & Collins, 2009). Therefore, teachers have many tasks to accomplish during class time rather than solely focusing on vocabulary. This pressure is compounded for ELLs in content area classes where they must learn the subject matter while simultaneously developing L2. Thus, class lesson plans can be so packed that adding in a vocabulary module almost seems inconceivable for most teachers. As vocabulary is generally considered a self-directed phenomenon (Nation, 2013; Nation & Webb, 2011), there has been evidence that teachers sacrifice vocabulary instruction for other language related activities (Nation, 2016). As a result, learners are left to learn vocabulary and improve their mental lexicon on their own in most cases.

A further issue related to vocabulary instruction is the choice of strategy domain. Ellis (1990) and Long (1998) argue that intentional vocabulary instruction has always yielded a better learning outcome in terms of breadth of word knowledge rather than only sticking to vocabulary developing through receptive modes of language. Incidental learning, however, is sometimes misinterpreted as unconscious way of learning new words. Therefore, Gass (1999) believes that the learner is not inactive in incidental learning, claiming that incidental learning should be the side effect of other learning activities. Along the same line, R. Ellis and Shintani (2014) investigated incidental vocabulary learning through exposing learners to input data. They argue that learners have acquired some L2 linguistic properties as a result of the indirect exposure.
Likewise, Nation (2001) distinguishes intentional learning from that of incidental learning, arguing that intentional learning is form-focused while incidental learning is message-focused. However, N. Ellis (1999) sees the scenario from a different viewpoint, claiming that the type and amount of attention that students put on every lexical item makes a distinction between incidental and intentional learning. He further argues that, in incidental learning, students put their focal attention on meaning rather than on linguistic form in intentional learning.

In a nutshell, mainstream teachers with ELLs in their classes seemingly lack resources for assisting emergent bilinguals with vocabulary development. They also seemingly and simply may not feel they have the time to work on vocabulary as part of their content lesson planning. A key goal of this dissertation is create a tool that can potentially assist these teachers, and more importantly, their students when lexical features become impediments in students’ work toward content understanding.

**Statement of the research problem**

Having reviewed the recent literature on vocabulary, one might wonders which vocabularies should be taught first. A further issue then would be what new academic and STEM-related word lists are designed for teaching vocabulary and reading that could work as a versatile tool for both teachers and learners? These questions point toward a focus on classified word lists and sub-lists (frequency-based, academic and STEM-related word lists) that may be matched with the common needs of K-12 students in heterogeneous classes. However, none of the existing word lists (Coxhead, 2000; De Gardner & Davis, 2013, West, 1950) has ever focused on the K-12 context. Hopefully the current research
study covers the gap of the existing lack of a validated word list for ELLs in the K-12 context and will advance field of vocabulary instruction.

On a pedagogical and curricular level, we should set reasonable goals at each level through which learners will be able to use an L2 efficiently. Such a goal should have a clear and meticulous plan in terms of the number of words that should be taught through a language course. However, there is not a fixed reasonable number of vocabulary words to pick up as an optimal number that should be covered during a particular time; the number of words is related to the learners’ proficiency level and motivational aspects, as well (Waring & Takaki, 2003). Research (for example, Goulden, Nation, & Read, 1990) indicates that the vocabulary size of an educated native speaker is approximately 20,000 word families, including inflectional and derivational forms. Nation (2013) posits that, in each year of one’s early years in life, native speakers add 1,000 word families to their vocabulary size. This statistical scenario would be different for ELLs with learning fewer words (Nation, 2013) at each level.

Another issue, in this regard, is that most mainstream classes are heterogeneous; in other words, students’ language proficiency levels and their needs differ. Therefore, teachers will find it difficult to give a task to the whole class with the focus on a specific theme, and in some cases there is no other option but to use individualized instruction. Meanwhile, the lack of an appropriate diagnostic placement test in some schools even worsens the scenario. Also, teachers will not have access to a diagnostic test which yields an assessment of ELLs’ proficiency. Or, even if they do, they may not have a sense of the degree to which their proficiency helps or harms their progress in a mainstream class. In such heterogeneous classes, teachers are then left with no option but to imagine the
vocabulary that could be the common need of all students. As a result of teachers’ decisions, language learning is not efficient and may discourage learners.

In order to improve teachers’ decisions on which vocabulary should be the focus of the learning, recent lines of research (Greene & Coxhead, 2015; Nation & Webb, 2011; Nation, 2016) argues that pedagogically-prepared word lists can offer the most efficient way to learn English vocabulary with an optimized context for instruction in each of four K-12 content areas through providing ELLs with the most frequent words in each area. The present dissertation examines word frequency in K-12 textbooks and how they may potentially foster effective vocabulary learning order.

**Research questions**

The purpose of the dissertation study is to develop new word lists as well as a mobile app alongside a website. The following research questions have been identified that will be the focus of the rest of this research study.

1) What is the frequency distribution of vocabulary in U.S.-based K-12 textbooks?

   a) To what extent are

      i) K1 (1,000 most frequent words),

      ii) K2 (second 1,000 most frequent words),

      iii) academic words, and

      iv) off-list words

   represented in U.S.-based K-12 textbooks?
2) What are the most commonly used lemmas in U.S.-based K-12 textbooks?
   a) To what extent are
      i) high-frequency,
      ii) medium frequency, and
      iii) low frequency lemmas,
      used in U.S.-based K-12 textbooks?
   b) What are the new academic and STEM-related word lists in U.S.-based K-12 content area textbooks?

3) What is a new mobile app alongside a website to teach vocabulary and reading to ELLs as well as mainstream students?

   **Overview of methods**

   For the purpose of this research study, I created two corpora, the Teacher’s U.S. Corpus (TUSC) and the Science and Math Academic Corpus for Kids (SMACK). Each corpus yielded key vocabulary lists with lexical items ordered according to each item’s frequency within each corpus. To create these corpora, I collected and analyzed a total of 122 textbooks. The recruiting, scanning and converting of textbooks had been carried out over a period of more than two years from October 2014 to March 2017. In total, this school corpus contains 10,519,639 running words and 16,344 lemmas saved in 16,315 word document pages (see Chapters 3 and 4 for information on the methods employed in the current study).

   Finally, the resulting lists have been operationalized into a mobile app. Cooperating closely with a computer team over the past two years, I designed and developed a mobile
app (Vocabulary in Reading Study – VIRS, available on iOS, Android, and Google Play) alongside a website (www.myvirs.com) that apply these new corpora and word lists to teach reading and vocabulary through a color coded system. The development of that app is described in Chapter 5.
CHAPTER II

Conceptual framework and literature review

Introduction

This corpus-driven study covers several topics ranging from word retrieval, text density and corpus development to word list validation. In this chapter, I review important theories that form the conceptual framework for this study. Specific topics include the following:

1) Typology of academic vocabulary,
2) Word frequency studies in the context of vocabulary instruction strategies and lexical development,
3) The necessity of new school word lists for ELLs, seminal studies on threshold level and text density,
4) Processes through which human being learns and develops vocabulary,
5) Problems with current word lists,
6) Academic word lists, and
7) A detailed definition of corpus linguistics and its application in classroom

Conceptual framework for this dissertation

The conceptual framework of this study is founded on three pillars: 1) text coverage and learning burden, 2) typology of vocabulary, and 3) a vocabulary learning model including word frequency.
Text coverage as a criterion for learning burden

How much vocabulary does anyone need to know in order to read a text? According to Chall (1987), there is a bilateral relationship between vocabulary knowledge and successful reading. Koda (1989) examined the correlation between linguistic knowledge and reading comprehension. Results show that vocabulary knowledge has a correlation of r = .74, which accounts for 55% of successful reading. In another study, Komori, Mikuni, and Kondo (2004) reported that 47% of reading success is accounted for by word knowledge.

Bernhardt (2005) claims that vocabulary knowledge accounts for 30% of successful comprehension. Hu and Nation (2000), however, claim that learners need to know 98% of the text to gain a reasonable comprehension. In this regard, we can relate text coverage, which is defined as the coverage percent of a text by different levels or tiers of vocabulary (Nation, 2013), to learning from meaning focused input which could be achieved by 95% text coverage (Nation, 2001). Thus, text coverage is an invaluable quantitative measurement to assess the value of a level of words as a sublist or domain-specific vocabulary (Coxhead & Hirsh, 2007). Indeed, reading comprehension in L2 can be relatively improved by controlling vocabulary through word lists (Nation, 2016).

Learning burden

The same causal relationship has also been claimed with learning burden, as a low text coverage has a heavier learning burden (Nation, 2001). Nation (1990) argues that the amount of energy needed to learn a word is its learning burden. He thinks that L2 previously learned information and learners’ L1 are the main sources that lead to learners’
familiarity with word patterns which lightens the learning burden. If every word and every word part in the world were different, then the vocabulary learning burden would be abundantly thick. However, fortunately, words are made up of different parts, inflectional and derivational affixes, as well as a stem; thus, word knowledge involves composing the word parts. In terms of word coverage, then, many words with a low frequency of occurrence that have different parts will be reformed each time they are used. For example, the word *unpleasantness* is reformed from its parts (*un, pleasant, and ness*) where all the parts can work independently but also compose into a usable word.

**Learning burden of words in a second language**

There is evidence that the scenario of vocabulary learning is even worse at advanced levels of language learning. According to the ACTFL model of inverted pyramid (ACTFL Proficiency Guidelines, 2012), five proficiency levels have been delineated, namely *distinguished, superior, advanced, intermediate, and novice*. ACTFL model claims that progress from one proficiency level to the next requires a higher vocabulary size and sophisticated lexical network as well.

In my experience as an English language learner, which was the initial impetus leading me to this dissertation study, I remember that I was faced with more challenges when I was at my advanced level because I felt that I did not have reasonable progress in learning English. My own experience corresponds with the approach taken by ACTFL, not only as a student, but also as a language instructor. Years later, when I became an English teacher, I often heard that my students complained about their slower learning rate and heavier burden that they had in reading comprehension. To this end, indeed, some theorists
(e.g., Nassaji, 2012; Nation, 2013) suggest that the phenomenon of heavy learning burden among second/foreign language learners is the result of a decrease in text coverage.

**Lemma vs. word family**

**Lemma**

Francis and Kucera (1982) argue that a headword is the main part of a lemma alongside only some of inflectional forms and reduced forms as well. Therefore, all the words that go under the platform of lemma are the same part of speech. Past tense, past participle, plural form, comparative and superlative are the major English inflections.

Lemma has been used in the literature on lexicon studies as the unit of counting. Thorndike & Lorge (1944) used lemma in their study for frequency counts. Francis and Kucera (1982) developed a lemmatized list from a computerized version of Brown corpus. In the present study, comparative and superlative forms were not included in the definition of lemma. However, different spellings are considered as the same lemma (e.g., *favor* and *favour*).

Nation (2013) believes that the learning burden of lexical items is correlated with the use of lemma and inflectional system. For example, if a learner knows the meaning of *mend*, the learning burden of *mends* then would be negligible. However, a challenge with regard to the definition of lemma and the question that which forms should go under a headword in lemma is our decision about irregular forms like *best*, *mice*, and *went*. There is no doubt that the learning burden of such irregular forms is heavier than that of regular verb forms such as *talked*, *typed*, *cats*, and *easiest*. However, it is still open whether irregular forms should be taken as a separate lemma or put under the same lemma group.
A further issue with regard to the definition of lemma is the separation made between the adjective, noun and verb forms of related items such as *bank, original*, and *display*.

A further issue with regard to lemma in the lemma-based classification is the choice of headword whether it should be the base form of the entry or the most frequent one. Because lemma has fewer forms, applying lemma as the unit of counting of entries in a corpus will reduce the number of entries and consequently the final learning burden of a particular lexical item. Bauer and Nation (1993) converted the 61,805 word type-based corpus to a 37,617 lemma-base corpus showing an approximate 40% reduction.

**Word family**

Word families consist of a base word alongside its inflectional and closely related derivational forms. Some derivational forms in a word family such as *–ness, -ly* and *un-* are the affixes that reduce the learning burden of words containing these derivational forms by being used systematically in word formation process.

A major issue with regard to the use of word family is the fact that the lexical items that should be included under a word family are not clear. In this respect, Nation (2013) claims that learners are different in terms of their current proficiency level; meaning that, second language learners’ knowledge of suffixes and prefixes are different. Nation then argues that in developing a scale of word families in a corpus, we should start from easier words (words with less affixes) to more complicated ones.

In this regard, Nation (2013, p. 15) argues that the text coverage of first most frequent 1,000 lemmas (which refers to a particular form of a word family that represents the lexeme and is the main dictionary entry for a word family) is between 71-85% in Brown
corpus; however, this range plunges to 4-6% for the second most frequent 1,000 lemmas. Therefore, while one’s vocabulary learning rate is most probably consistent at the advanced level, a huge drop in text coverage results in fewer encounters with learned words, consequently imposing a poor return on one’s language learning effort, particularly with respect to vocabulary learning. While vocabulary coverage is problematic enough, one’s retention rate in both intentional and incidental vocabulary learning can also be low (Ehsanzadeh, 2012; Nassaji, 2012; Nation, 2013), a phenomenon that indisputably affects students’ learning motivation in general and their language learning passion in particular.

Causes of vocabulary learning burden in a second language

Frequency of lemma

Bauer and Nation (1993) used the criterion of frequency (among other criteria) to organize the patterns of word construction into different proficiency levels. They argue that the learning burden of a word is related to the knowledge of its word parts and the frequency of lemma. Therefore, one may argue that an important part of learning burden is related to the frequency of word family (Nation, 2013). Along the same line, Nagy, Anderson, Schommer, Scott, and Stallman (1989) believe that the total frequency of a word family (total frequency of all forms of a lemma including affixes and the word root) is a reliable predictor of the speed of word recognition.

Word retrieval

Word retrieval is the memory function that also causes a heavy learning burden. Baddeley (1990) argues that repeated opportunity is important to word retrieval. He
believes that word frequency improves the quality of retrieval and thus strengthens the form-meaning link which subsequently leads to enhanced retrieval in future. With regard to learning vocabulary in an L2, word lists can be helpful tools in providing learners with the proper opportunity to encounter new words and strengthen its memory trace before it is sent deep down into long-term memory.

**Patterns of word appearance**

According to Schmitt (2014), depth is the quality of knowledge about how well different aspects of a word are known, while breadth of knowledge is the number of known words at a particular point. In other words, knowing a word is not unidimensional, as knowledge about a word involves syntagmatic and paradigmatic information about depth and breadth of word knowledge. As a result, another aspect of learning burden of words could be attributed to systematic patterns of word appearance.

A rule of thumb is that not all words in a language are equal in their role in comprehending the language and expressing thoughts. Word frequency research (Coxhead, 2011; D. Gardner & Davies, 2013; Nation & Webb, 2011) reveals that some high frequency words are more beneficial in helping learners to use an L2 effectively. Alongside, there is a small group of high frequency words that covers a big portion of everyday language use. This group should indisputably be the starting point in vocabulary instruction. While examining the Brown corpus, Nation (2013) claims that Level 1 vocabulary is the 1,000 most frequent words whose text coverage is about 72%. This frequency level in Cobb’s (2017) classification (Vocab profile through Lextutor website) is known as K1, which is the most frequent words (see later in this chapter for a detailed description of Cobb’s
classification). However, Level 2, the second 1,000 most frequent words that is known as K2 in Cobb’s classification, covers only about 7.7% of data. Not surprisingly, the trend takes a downward movement by hitting 4.3% of text coverage for Level 3 of 1,000 most frequent words.

Threshold level and the necessity of word list

The question regarding whether there is a minimum amount of vocabulary knowledge that marks a make-or-break boundary for whether one achieves successful comprehension has always been an interesting issue for reading and vocabulary researchers. The boundary is referred to as a threshold level. Nation (2001) believes that a threshold level can be defined in either of these two ways: The first view is the strong view, and Nation argues that threshold level is an either-or (all or nothing) level; in other words, the learner will understand the text if he passes the threshold level; otherwise, he will have a vague comprehension of the text. The second view, however, takes the threshold level as a “probabilistic boundary” (p. 238) and states that if a learner passes the threshold level, then he stands a good chance for a successful comprehension.

Laufer and Sim (1985a) took the second view of threshold level and attempted to examine it with interviews and comprehension questions. Results of their research show that the threshold level is roughly 65 to 70% of text coverage. They further claim that vocabulary knowledge is the learners’ primary need for successful comprehension. Laufer (1989b) later examined the needed percentage of vocabulary for successful comprehension. Results of her study show that a score of 95% and above on vocabulary will likely lead to the full comprehension of a text. However, results also show that the score of 90% on
vocabulary did not result in successful comprehension. Moreover, Laufer attempted to determine the amount of vocabulary size which is needed to reach the score of 95% on vocabulary. She agrees with Ostyn and Godin (1985) claiming that knowledge of 4,839 words will result in a text coverage of 95 to 98% of newspaper articles in Dutch. In regard to this claim, however, there are three major problems: First, results of vocabulary studies in Dutch do not necessarily apply to English. The second issue is that the unit of measurement is not clear of what a word is: whether it’s an individual word, a lemma, or a word family (Further discussion of these distinctions will be clarified in Chapter 4). The final problem is the genre of the corpus as newspaper articles may not be a proper representative of academic language. Nevertheless, Laufer did not stop there: In another study (1992b), she investigated the effect of vocabulary size on reading comprehension. She looked at the issue from different angles (known/unknown word ratio and level of comprehension) and finally claimed that the 3,000 level of word family on the Nation’s (2001) scale of word size (1,000, 2,000, 3,000, 5,000, and 10,000 word levels) is the confirmed threshold level.

Hu and Nation (2000) believe that the coverage of 80% of the text is the threshold level for the all-or-nothing view (the ELL will be on the verge of losing the meaning of the text) and 98% for the probabilistic threshold level. They further claim that 95% is the threshold level for a minimum of adequate comprehension in which the ELL will comprehend the basics of the text. Nation then argues that the type and length of the text are main factors which affect desired text coverage (Nation, 2001). In a recent study, Schmitt, Jiang, and Grabe (2011) believe that there should be a positive relationship between reading scores and text coverage; however, they doubt the existence of a
confirmed threshold level. Although precursory research is not clear about the existence of a numerical threshold level and the minimum number of needed vocabulary, we may wonder if the use of word lists might have a direct correlation with improving text coverage.

**Typologies of academic and STEM-related vocabulary**

The most recent typology of academic vocabulary divides into three categories, which have common grounds as well as some differences. Below, I give a brief description of these three typologies.

Fisher and Frey (2008) argue that words in a language should be grouped into three main categories: 1) general words which are high frequency words that people basically need for reading; 2) specialized words whose meanings are domain-specific and appear in a wide range of texts; and 3) technical words that are content-specific terms and appear only in a few content areas.

Harmon, Wood, and Hedrick (2008) divide academic vocabulary into four classifications: 1) word clusters; 2) symbolic representations; 3) academically technical terms; and 4) nontechnical terms. Their last two groups of words are similar to Fisher and Frey’s (2008) technical and specialized vocabulary. The first category, word clusters, refers to clusters or phrases of words that appear only in a particular domain. Symbolic category are also symbols and special abbreviations related to a domain.

Taking a different point of view with regard to academic vocabulary, Hiebert and Lubliner (2008) classified the vocabulary system on the basis of frequency and dispersion. They define frequency as the number of times that a word appears in a given text.
Dispersion, however, refers to how widely a word is used across different subject matters. A low dispersion value, thus, shows that a word appears within only a few content areas.

Hiebert and Lubliner’s (2008) classification system includes four vocabulary categories: 1) school task vocabulary, 2) general academic vocabulary, 3) content-specific vocabulary, and 4) literary vocabulary. The content-specific vocabulary in this system is close to domain-specific academic vocabulary. Hiebert and Lubliner’s general academic vocabulary is also analogous to Coxhead’s academic vocabulary.

Among the four classifications proposed by Hiebert and Lubliner's (2008), school task vocabulary is more related to my dissertation. This category includes the words appearing within English language arts as well as terms and expressions that classroom teachers use in their teaching. School task vocabulary also covers language that textbook writers use to describe educational concepts.

Since 1994, Tom Cobb has been developing a website—LexTutor (see Chapter 3 for a description of the website)—which gives a variety of options for lexical and textual analysis. Cobb argues that a comprehensive vocabulary profiler should divide a text into four basic word groups, including both frequency-based and content-based classification. Cobb’s frequency-based classification has two categories—K1 which is 1,000 most frequent words, and K-2, the second 1,000 most frequent words. On his website’s vocabulary profiler, K1 words are color coded as blue and K2 in green. Cobb’s content-based classification, AWL, mostly follow Coxhead’s Academic Word List (AWL) and comes in yellow. In Cobb’s classification system, there’s also a category known as Off-list, which comes in red in the website’s profiler, and presents words that are not represented in the K1, K2, or AWL.
Vocabulary classification system for this study

The line of literature on academic vocabulary divides it into two major categories: 1) domain-specific or content-specific words particularly used in a content area such as biology, geometry, physics, and algebra, and 2) general academic vocabulary which is an all-purpose category of academic words that appear across a range of academic content areas; however, their meanings may vary from one discipline to the other. For the purpose of this dissertation, I classify academic words into 1) academic vocabulary and 2) STEM-related words.

Word frequency list and vocabulary instruction

Mental lexicon and word frequency

The mental mechanism of vocabulary learning through intentional learning (word list) and incidental learning (lexical inferencing) does not yet stand both theoretically and empirically clear. Within this line of research, as Baddeley (1998) claims, the mental status of lexical items and their retrieval is the area of neurological research that lags behind other related areas and needs more bodies of research. In this regard, an influencing factor on both incidental and intentional learning is word rehearsal. Alongside, there is a gap in literature with respect to the retrieval of learned lexical items through word lists. The line of research on lexical inferencing is fairly rich (Nassaji, 2004; Nation, 2001; Soria, 2001); however, few research studies on the effect of word lists on the retrieval of learning in the mental lexicon are available the mental dictionary represented in the mind through which individuals are able to engage in everyday processes of language use.
Word Frequency and vocabulary development

One possible reason for a low rate of vocabulary learning might be a result of one’s little exposure to language. Sometimes, L2 classroom exposure is the only chance that learners have in the process of language learning (Chen & Truscott, 2010; Schmitt, Jiang, & Grabe, 2011; Waring & Takaki, 2003; Webb, 2007; Webb & Chang, 2014). Zipf (1949) proposed a linear relationship between frequency rank and probability of its usage. He argued that more frequently used words are easier to process. Also, psycholinguistic research has repeatedly confirmed the influence of word frequency on language processing phenomena such as lexical decision tasks (Rubenstein, Garfield, & Millikan, 1970), word naming tasks (Ellis, 1991; McLaughlin, 1990), phoneme monitoring (Nation, 2001), and lexical access (Balota & Spieler, 1999). Gass, Behney & Plonskey (2013) believe that the first encounter with a word may draw a learner’s attention to that item. Subsequent encounters provide learners with further opportunities to determine relevant semantic and syntactic information. This further means that the salience of a word through frequency helps learners become aware of the word as an item they need. Nagy, Herman, and Anderson’s (1985) study shows that native English speakers have about a 10% chance of learning the meaning of a new word in their home language from context given a single exposure; however, second language learners likely require many exposures to a word in a context before understanding its meaning.

To explore the relationship between word frequency and retention trend, Rott (1999) argues that exposure frequency is the variable that influences the forgetting pattern of word learning. In another study on retention rate, Brown (1993) found a clear relationship between general word frequency and the words learned by learners. He used
the Brown corpus as a norm of reference. Nation (2001) argues that word frequency directly affects learner’s noticing through the salience of a word in the context. However, a key question arising from the research can lead one to propose that one should have a great deal of exposure, but only if one actually notices it before learning it. As a result, word salience and frequency seemingly affects a learner’s realization that a word is significant in filling an existing gap in any person’s knowledge (Schunk, 2012).

Webb (2007) examined the effect of word repetition of developing word knowledge. Participants were 121 Japanese EFL learners assigned randomly to one control group and four experimental groups. The design of the study uses one vocabulary comprehension task with 10 tests to measure different aspects of vocabulary knowledge, namely syntax, grammatical function, and association. Webb used pseudowords with 1, 3, 7, and 10 frequency of occurrences. Results of the study showed that repetition has a positive effect on at least one aspect of vocabulary knowledge. However, Webb claims that 10 encounters with a word or maybe more are required to learn all aspects of a word.

As a follow-up to Webb’s (2007) study, Chen and Truscott (2010) also investigated the effects of repeated encounters with target words on the development of seven aspects of word knowledge. They used seven measures in their study, immediately after the treatment and again after a two-week delay. The design of the study was a follow-up of Webb’s (2007) study but emphasized ecological validity over control and presenting genuine words in meaningful reading passages. Results for repetition largely supported Webb’s findings while suggesting that the nature of his study led to an overestimation of learning. Chen and Truscott (2010) also argued that in the immediate posttest, repetition
affected productive vocabulary knowledge somewhat more than receptive one, but this relation reversed on the delayed posttest.

Literature on optimal word frequency (Laufer, 2003; Nation, 2001; Nation & Webb, 2011) argues that a range of 8 to 12 exposures of new words are needed for a learner to start using new lexical items in L2. Other studies (Kweon & Kim, 2008; Waring & Takaki, 2003) also reported that word frequencies greater than 20 are needed for incidental learning. In their study, Waring and Takaki used a multiple-choice, immediate posttest measure and found that of 25 new words available for learning in a graded reader, 11 words were learned, indicating a gain of 44%. However, some studies have shown that vocabulary learning occurs from as few as five exposures (Webb, Newton, & Chang, 2013) and even two exposures (Bisson, van Heuven, Conklin, & Tunney, 2015).

With regard to word attrition trends in vocabulary learning, Ellis (2002) argues that incidental learning from extensive reading can sometimes be connected to the short-term memory processes, and the learner may be unable to recognize or use the word on future occasions. However, Ellis also suggests that higher frequency words in the incidental learning will create connections between short-term memory (STM) and long-term memory (LTM) which would diminish the word attrition trend. The rationale behind this is that the first few encounters serve as an attention raiser—that is, noticing. The subsequent encounters direct the learner’s attention toward the word, and thus lead to the acquisition of the word meaning. Ellis argues that multiple rehearsals in unique situations will connect STM with LTM. He claims that if constructing word meaning through lexical inferencing is connected to STM, the reader cannot recognize the word and would not be able to retrieve it in future.
Schunk (2012) argues that rehearsal is one of the situated factors that has a direct correlation with word learning. Also, Laufer (2003) believes that rehearsal should occur at least eight to 12 times in order for a learner to be able to retrieve an item. She thinks that the rehearsals should be in different situations through different learning activities. In a similar study, Horst (2005) claims that the reason behind this may be because the first few rehearsals attract the attention of the reader and further rehearsals give the chance to the reader to construct the meaning on the basis of the available clues that he/she has of the situation, the co-text of the reading passage. The further rehearsals of the word in different situations allow the reader to confirm or reject earlier inferences.

**A model for learning vocabulary in another language**

There are a number of studies attempting to formulate a model for the role of frequency categories in vocabulary learning and retrieval process (Coxhead, 2000; Crossley, Cobb, & McNamara, 2013; D. Gardner & Davies, 2013; De Bot, Paribakht, & Wesche, 1997; Nation & Webb, 2011; Schunk, 2012). In the present study, I focus on word frequency and the role of academic and STEM-related lists that provide learners with a content choice through corpus. The learning context in the model I designed for the purpose of the research study is reading in which K-12 students, including ELLs, receive input and can utilize contextual and situated clues to construct meaning. My perception is that the process of the development of lexicon through reading is a holistic process starting with inferring the meaning of unknown words. Successful inferencing seemingly leads to the comprehension of the reading text (in our case, K-12 textbooks). When students achieve comprehension and are able to synthesize and construct the whole meaning of the reading
passage, this then means that they learned the unknown lexicon passively. It is here is where word frequency comes to play. Learning the new lexical items and transforming them into LTM occur simultaneously (Schunk, 2012). This does not necessarily guarantee that comprehension leads to the retrieval of lexicon for future use; thus, learners should encounter the word on an organized and regular basis. As is illustrated in the diagram below, vocabulary learning and its retrieval for future use are two distinct constructs (Schunk, 2012).

A number of factors seem to affect the retrieval of lexical items through both intentional and incidental learning, among which inferencing, depth of processing in the mental lexicon, and word frequency outstand the others. How word frequency affects the learning process is presented in the model in Figure 2.

**Encoding and internal specification**

Analyzing the new information in working memory (WM) and breaking it down in chunks to be stored in long term memory (LTM) is technically known as encoding (Schunk, 2012). Matlin (2009) believes that encoding is initially accomplished by giving a code to the received information and then that code is linked to the existing codes in the LTM. Meaningful encoding improves the retention rate of stored information in LTM and learning occurs even with meaningless encoding. Although teachers attempt to present words in meaningful ways and most students also attend to teachers’ explanation (Greene & Coxhead, 2015), there are things that still go unlearned in class—for example, ELLs’ poor use of academic words in their writing samples). With this regard, Schunk (2012)
argues that organization and elaboration are two main factors that affect encoding and internal specification.

**Organization**: Organization, as shown in Figure 1, has a direct effect on encoding and internal specification through depth of word processing (Schunk, 2012). Research (Anderson, 1990; Miller, 1956) showed that the more materials are organized, the easier they will be retained. When smaller bits of a whole information are linked together systematically and are also linked to stored information in LTM, remembering of one chunk stimulates other related items and thus makes it easier to recall the whole information. Using a hierarchy of information in which chunks are integrated is one way to organize the information.
Figure 2. A model for learning vocabulary in another language.
**Elaboration**: Schunk (2012) believes that elaboration is the procedure that enhances encoding processes in WM through linking a new item to the conceptually related schemata in LTM. Today, neurologists believe that elaboration improves word retrieval through linking a new word to the network of active vocabulary knowledge. In this regard, Anderson (1990) argues that sometimes people forget the message but elaboration helps to recall the key content. Elaboration is important because a problem that many students, including English language learners, have in developing their word knowledge is that they cannot appropriately elaborate the new vocabulary items because it is not easy to link every new vocabulary to the network of lexical repertoire Anderson, 1990).

**Depth of processing theory**

Depth of processing theory, also known as the Levels Theory, defines human memory on the basis of the nature or the type of the required processes through which brain receives information rather than the place of the information (Craik & Tulving, 1975; Lockhart, Craik, & Jacoby, 1976). Lockhart et al (1976) argued that depth of processing in learning vocabulary will occur better if students understand materials and process them at a deeper level. They further claimed that drawing on students’ schemata will enhance learners’ retrieval. According to depth of processing theory, one significant method in improving retrieval is through providing further processing at the same level. In this regard, Nelson (1977) provided his students with either one or two additional rehearsal for each word. He argued that two repetitions produced much better rehearsal.

Anderson (1990) in his activation model of memory rejected two separate structures and instead argued for a holistic model of memory with two activation states, namely as
active and inactive. At every point of time, information may be processed at the active or inactive states of mind. According to Anderson’s model, frequently encountering new words keeps the memory of the word traceable in the active state of the memory which consequently leads to a higher chance of learning. However, by shifting the direct attention, the memory activation state will then change.

Rehearsal theory

Spaced rehearsal strengthens the trace of memory. Schunk (2012) argued that rehearsal is of two types: maintenance rehearsal and elaborative rehearsal. Maintenance rehearsal is reviewing the new material repeatedly which could be accomplished through putting an exponential space between each rehearsal. In elaborative rehearsal, students relate the new information to what they already know and stored it in their LTM. A mnemonics approach to developing vocabulary (Ellis, 1994) is a form of elaborative rehearsal. For example, if a student is studying U.S. history, and for a number of times “D-Day” is repeated that “D-Day” was June 6, 1944, this is maintenance rehearsal. However, if he relates it to the information that he knows (e.g., Roosevelt was selected for the fourth time in 1944), this will be elaborative rehearsal. When it comes to word learning, this process is more difficult because we have a huge number of abstract words whose linking to schemata needs students’ effort and teachers’ creativity, as well.
Corpus linguistics

Corpus-based research

Corpus-based research has been shown to provide us with tools for explaining variation and use of linguistic patterns (Tognini-Bonelli, 2001). This means that the goal here is to investigate the systematic patterns that governs the linguistic features. Biber (2012) argues that corpus-based research has systematically illustrated that any language variant is distributed with a different frequency across different registers. The use of computer programs has caused corpus-based research to be highly reliable and with an acceptable validity (McEnery & Hardie, 2013).

Corpus-based study is a top-down approach in which grammatical features are described. The term corpus-based is used to refer to a methodology that avails itself of the corpus mainly to expound, test, or exemplify theories and descriptions that were formulated before large corpora became available to inform language study. In this regard, Biber (2012) argues that corpus-based research is criticized for ignoring the evidence that fails to fit through the confirmed theories while mostly attaching to existing pre-corpus theories.

We could say, therefore, that corpus-based linguists adopt a “confident” stand with respect to the relationship between theory and data in that they bring with them models of language and descriptions which they believe to be fundamentally adequate, perceiving and analyzing the corpus through these categories and sifting the data accordingly. The corpus is considered useful because, on occasions, it indicates where minor corrections and adjustments can be made to the model adopted, and it can also be valuable as a source of quantitative evidence (Hunston, 2006). In this case, however, corpus evidence is brought in as an extra bonus rather than as a determining factor with respect to the analysis, which
is still carried out according to pre-existing categories; although it is used to refine such categories, it is never really in a position to challenge them as there is no claim made that they arise directly from the data.

**Corpus-driven research**

Corpus-driven analysis uses the unique features of a text to determine linguistic categories. This means that corpus-driven research considers corpus evidence (Tognini-Bonelli, 2001). Therefore, all linguistic categories are systematically derived from frequency distributions. Unlike corpus-based research, corpus-driven analysis only deals with words and syntax, and grammar has no place in this approach so that all inflectional and derivational morphemes of a single lemma are treated differently. This, however, does not mean that all cases of corpus-driven studies are the same. They are different in one of these three ways: whether they analyze lemma or word family, the extent to which they use linguistic constructs, and the role of frequency in analyzing the data (Biber, 2012).

A corpus-driven approach aims to derive linguistic categories systematically from recurrent patterns and frequency distributions emerging from language in context (Tognini-Bonelli, 2001). This approach is similar to a holistic approach to language in that the cumulative effect of repeated instances is taken to reflect the semiotic system; the text is seen as an integral part of its verbal context and, ultimately, no discontinuity is assumed between this and the wider context of learning situation, and the even wider context of culture.

Using corpus evidence as the main source of analysis makes the corpus-driven research a bottom-up approach in which the researcher starts the analysis with having no
assumption in mind. As a result, a major criticism to corpus-driven study is that it wholly adheres to the obtained data from the corpus, which in some cases is not necessarily a pure display of real language (Leech, 1991).

**Current word lists**

In curriculum design and material development, making word lists to provide new tools for teaching different genres of vocabulary has a long history. Early lists (non-frequency lists) did not implement a frequency calculation. The word selection criterion then was determined by the word’s significance in meaning conveyance. The Basic English word list (Ogden, 1936), for example, is one such attempt that focused on the words learners need to produce a wide range of linguistic output. In the Ogden’s list, however, most words are high-frequency words (Nation, 2016).

The latest version of such non-frequency based lists is Carter’s (1987) core vocabulary. His point of view is that determining core vocabulary with only a linguistic focus is insufficient. Carter believes that making pedagogical word lists needs a clear decision over which words should be taught first. He further claims that a rigorous selection of core vocabulary in making word list will lead to the grading of reading materials and lexical richness.

In the second category of word lists, frequency-based lists which emerged as a result of a collected corpus, the best known is West’s (1953) General Service List (GSL) that presents levels of what he claimed were the 2,000 most frequent academic words in English. The GSL had been used extensively in ESL and ESP classes. West also used other criteria beyond the frequency in developing his list as he was busy with developing graded
readers. Ultimately, West included words that were not high frequency words but turned out to be words that are essential in producing basic meaning.

In an attempt to develop a content area corpus, Salager (1983) created a corpus of medical English with 100,000 running words. He divided the corpus into three subcorpora: basic English, fundamental medical words, and technical words. In developing his word list, Salager compared her medical corpus with another diverse corpus to analyze the role of semi-technical vocabulary in academic discourse.

In the hope of making a stronger word list with a higher text coverage, Xue and Nation (1984) combined four word lists developed by Campion and Elley (1971), Praninskas (1972), Lynn (1973), and Ghadessy (1979), thereby composing the University Word List (UWL). In developing the UWL, Xue and Nation for the first time used two computer programs, Vocabulary Profile and Range Program, developed by Nation and his colleagues. The list has 836 word families and had been widely welcomed and used for more than 15 years in academic settings.

Similarly, Farrel (1990), in his study, focused on semi-technical words and made a list that contains 467 family types and 160,000 running words. Farrel defines semi-technical words as those that are context independent and are beyond the words found in basic English courses. He attempted to exclude all general words from the list.

However, Ward (1999) criticized the idea of dividing a corpus into three subcategories of general, technical, and academic word levels. In other words, his notion was that dividing was not necessary—only context. Ward created an engineering corpus (Ward, 2009) from which he derived a list of frequent words. He then compared his list with a collection of engineering texts. Results of his study show that a list of 2,000 word
families covering 95% of engineering texts. Ward claims that the coverage of his list is more effective than that of GSL.

**Academic word lists**

All the word lists developed after the GSL have never gained the reputation of Coxhead’s (2000) Academic Word List (AWL), a seminal academic word list widely used in ESP programs. Through the process of developing the corpus, Coxhead applied four main criteria:

a) representation (a corpus must be a collection of texts that are representative of a variety of genres),

b) organization (words in a corpus should be selected evenly across subject areas),

c) size (word families with at least 100 occurrences were included in the corpus), and

d) word selection (the word family as the word unit for the corpus).

Coxhead collected 414 texts with approximately 3.5 million running words. She divided the corpus into four main areas of arts, law, science, and commerce. Each area contained roughly the same number of running words. In developing the academic word list, Coxhead used the Range program (Heatley & Nation, 1996) to rank order the words of the corpus alphabetically. The Range program is software that accepts 32 different files and produces a list of individual words with their frequency. Coxhead then applied three criteria for choosing the words of the AWL. According to the first criterion, *specialized occurrence*, word families should not be any of the members of the first 2,000 words of the West’s
(1953) GSL. *Range* was Coxhead’s second criterion, which placed a minimum of ten occurrences in each of the four areas for a word to be included in the word list. Through the third criterion, *a minimum*, Coxhead put a minimum of 100 occurrences in the Academic Corpus for all the members of a word family to be considered as a candidate for the AWL. After running the RANGE program (Nation, 2001) and comparing the results with West’s GSL, 570 word families met these three criteria for inclusion in the AWL.

The AWL text coverage accounts for 10.0% of the total tokens of the Academic Corpus. Among the four subcorpora, commerce has the highest AWL coverage with 12.0%. This amount is approximately the same for law and arts subcorpora with percentages of 9.4 and 9.3, respectively. Science, however, has the lowest AWL’s coverage (9.1), revealing that science seems to be easier than other areas, in other words, the more AWL abstraction in a text, the more difficult the text is considered.

In order to validate the AWL, Coxhead further developed another corpus of fiction texts containing more than 3.5 million running words. In this corpus, the AWL covers only 1.4% of the total tokens, demonstrating that most of the word families in the AWL carry concepts that are mainly associated with academic genres.

Over the past decade, Coxhead’s AWL has been used widely in efforts to reduce the gap between high and low second or foreign language learners in terms of academic word knowledge. However, Gardner and Davies (2013) argue that Coxhead’s list suffers from two main problems. The first issue concerns the use of word family as the base for making the corpus and counting the items of the AWL. Gardner and Davies believe that all the members of a word family do not share the same meaning and this would be more intense across different academic disciplines. They posit that this problem is caused
because word families in the list do not have parts of speech. Instead, they suggest that an academic word list should be arranged by lemmas (words which are from the same parts of speech and are related together through different grammatical inflections). Ultimately, they claim that a new academic core vocabulary is needed.

A further issue with respect to the validity of the AWL is its relationship to the GSL (West, 1953), as Coxhead extracted the words that were beyond the GSL’s first 2,000 high-frequency word level. Gardner and Davies, however, argue that the GSL is old and the corpus from which West made his list is from early 1900s. Therefore, Gardner and Davies believe that the AWL should not be attached to the GSL as the AWL is a category of the high-frequency words of recent English, while the GSL is not a meticulous reflection of the high-frequency words.

They further argue that a validated list should be drawn from a large and representative corpus that covers significant academic disciplines to be able to distinguish high-frequency words from academic technical words as well as from academic core vocabulary. Materials chosen from contemporary English are the characteristics that Gardner and Davies emphasize, proposing that texts and materials from 20 to 100 years ago would not make a valid word list. Moreover, they think that the best way to determine the validity of a word list is through comparing it to both academic and non-academic corpora. In doing so, Coxhead tested the AWL against a corpus of fiction texts, while Gardner and Davies also tested their list against a subcorpus of non-academic texts from the Corpus of Contemporary American English (COCA) which is a public domain and free corpus of English. Davis (2012) argues that the COCA is the only balanced and representative corpus of contemporary American English widely used by researchers.
COCA now has about 560 million words and Davis claims that 20 million words have been added to COCA annually since 1990 when it had first been appeared. COCA is also related to other existing corpora of English and contains different sections for fiction, magazines, newspapers, and spoken and academic texts. In developing their academic vocabulary list (AVL), Gardner and Davies (2013) used a corpus of 120 million words, taken from the academic subsection of the COCA. The AVL corpus is approximately 35 times larger than that of the AWL. Furthermore, the AVL corpus is 20% larger than the British National Corpus (BNC) (BNC has 100 million words and includes samples of both written and spoken language which is designed to represent British English) in terms of academic portion. Like the AWL, a limitation to the AVL is that there is no spoken sample of academic language.

In addition, Gardner and Davies (2013) excluded all high-frequency words and technical academic words. In making their list, they included the lemmas whose frequency were at least 50% higher in academic corpus compared to that of non-academic corpus (ratio criterion). In the next step, they collected the word lemmas that occurred in at least 20% of the expected frequency in seven domains. Gardner and Davies then chose lemmas with a dispersion of at least 0.80. The final measure that they used in developing the list was the exclusion of all the domain specific words from the final list.

**Sight word lists**

Sight words are the highest frequency vocabularies. These are common words that no one needs focused attention to recognize and decode them. In school materials and especially for young children, sight vocabulary usually accounts for 75% of the written
texts so that these are the words that should be the focus of early vocabulary instruction (Flesch, 1955).

There are a few sight word lists, among which Dolch’s sight words (Dolch, 1936) list was developed in 1930s and ‘40s by examining the words that most frequently appeared in the books written for children. Dolch’s word list contains 220 basic words alongside 95 high frequency nouns. Dolch’s sight word list is the most famous one of such lists. However, his list is dated. No current sight word lists are recent or methodologically validated. To the best of my knowledge, no sight word list has ever been developed from recent K-12 school textbooks.

**Problems of current word lists**

A major problem of all the word lists, except than the one developed by Gardner and Davies (2013), is the fact that they use small size corpora, smaller than 5 million entries. Therefore, they lack the representative criterion. As a result of this small size, none of them, hence, is seemingly derived from a balanced corpus. A further issue is that texts from which these lists are made are relatively old and can not meet the needs of 21st century language learners. Therefore, this criterion might disqualify Nation and Hwang’s (1995) claim that GSL still works reasonably well. Seemingly, then, as a result of technological changes in the past two decades, no replacement to GSL and other word lists can result in a validated word list with a high text coverage and the scenario is much worse when it comes to K-12 settings.

The third problem concerns the way that the corpus materials were collected and analyzed. The scrutiny of most of these corpora had been affected because they were
compiled by hand because of limited computer programs at the time. For example, Campion and Elley (1971) and Praninskas (1972) used basic principles of frequency in developing their lists. Meanwhile, Lynn (1973) and Ghadessy (1979) only collected words for which learners annotated in their first language in the academic texts. Another major problem of all the existing word lists is the lack of textbooks from which these corpora have been taken.

Over the past decade, learner autonomy (Gardner & Miller, 1996; Holec, 1981) has attracted a good deal of attention as both a means and a goal in education. While learner autonomy in language learning has gained different forms, self-directed vocabulary learning through word lists has become a key in improving the lexical knowledge of children with limited proficiency as well as adults in ESP programs.

Research on vocabulary assessment (Read 1998; Schmitt, Schmitt, & Claphan, 2001) indicates that high frequency words are seemingly learned first. Therefore, a word list based on frequency order can be valuable in determining the amount of vocabulary needed for an acceptable proficiency at a particular learning stage as well as mapping the best learning order.

Teaching/learning implications of using word lists

Principle of least effort in language learning

There is a general law in every language (Nation, 2013) that some words appear in spoken language and written texts more frequently than other. Initial data analysis for the present dissertation, alongside other corpus-driven studies (Coxhead, 2000; Nation & Webb, 2011), reveal that a small percentage of words are high frequency and have a wide
range of usage covering a larger part of written texts. Still, there is a large number of low frequency words whose text coverage is relatively small. This is also in alignment with the “principle of least effort” (Zipf, 1949, p. 5) which states that a constant figure will be gained if the rank order of an item is multiplied by its frequency. Thus, if we follow Zipf’s general cost/benefit law which claims that the effort of learning high frequency words first will repay better compared to that of learning low frequency words, it stands reasonable that teaching high frequency words first will improve learners’ reading proficiency and their general language comprehension. High frequency words are encountered more often and learning these words first may be more beneficial to learners.

**Significance of using word lists in language learning**

As a result, it is crucial for curriculum developers and textbook writers to know which words and core academic vocabularies should be given first at a particular proficiency level. To this end, and given the significance of teaching high frequency and core academic words through word lists, I review the significance of word list research here.

Nation and Web (2011) believe that word lists have clear benefits for learners, teachers, and textbook writers. They list seven values of word lists and argue that these values are not limited to only these seven:

1. *Designing courses*: Word lists provide us with the most valid source of sequencing words at different levels of language learning; therefore, learners will receive the most suitable content in accordance to their age and proficiency level.
2. **Setting learning goals**: Each sub-list has a certain number of words and can be set as a goal for learners to achieve at the end of a stage. Nation (2006) attempted to find how many word lists with 1,000 words are needed to reach the goal of 98% coverage of a text.

3. **Guiding the creation of simplified texts**: Graded readers have been created and have become a form of simplified texts, which may be valuable sources for improving second language learner’ reading proficiency (Woodinsky & Nation, 1998). This further emphasizes the role of word lists in developing materials within a controlled vocabulary.

4. **Analyzing the vocabulary in texts**: Adjusting the vocabulary load of texts to the learners’ proficiency level can be accomplished through frequency word lists. There are some websites (Cobb, 2017; Davies, 2012) that are used to analyze the text density in terms of word tiers.

5. **Creating specialized word lists**: Word lists are highly valuable in designing English for Specific Purposes (ESP) programs such as Business English, Medical English, Hotel English, Plumber English, English for Scuba Diving, and so forth.

6. **Analysis of lexical richness**: The learner corpus or texts produced by learners can be used as an educational tool through which we can gain a better understanding of learners’ lexical repertoire (Granger & Rayson, 1998). In doing so, word lists are used to analyze the learner corpus and will help us to know the amount of vocabulary the learners actively or passively use at a particular proficiency level.
7. Guiding the construction of vocabulary tests: The Vocabulary Levels Test and the Vocabulary Size Test (Nation, 2001) are two procedures examining breadth of vocabulary knowledge that are constructed based on frequency lists.

Beyond these seven values listed by Nation and Webb (2011), the line of research on breadth of word knowledge (Beglar, 2010; Nation, 2001; Read, 1998) reports that there is a positive correlation between the frequency of a word and the possibility of knowing that word. This further substantiates the significance of frequency-based word lists in improving the retention rate of incidental vocabulary acquisition. In this regard, Ehsanzadeh (2012) found that words with a minimum text exposure of 20 stand a good chance (13.4%) of being acquired incidentally through reading. Results of his study show that a word list of sight vocabulary can exponentially improve the text coverage and reading comprehension as well.

**Significance and purpose of this dissertation**

The line of research on reading comprehension (Gass, Behney, & Plonskey, 2013; Nagy & Townsend, 2012; Webb & Chang 2012; Webb & Chang, 2014) argues that academic vocabulary knowledge is the prerequisite ability for gaining an adequate understanding from academic texts. It seems that digesting academic texts has a direct correlation with academic achievement and future prosperity. This further emphasizes the key role of academic and STEM-related vocabulary knowledge in students’ future career. It also argues that the significant role of this knowledge has been well credited in primary
school (Chall, 1996; Biemiller, 2010), middle school (Townsend & Collins, 2009), and high school (Vacca & Vacca, 1996).

In the meantime, educators and school experts have acknowledged the need for developing new materials and effective strategies aimed at improving ELLs’ academic and STEM-related lexicon (Beck, McKeown & Kucan, 2002; Biemiller, 2010; Carter, 2012; Gardner, 2013). Materials focusing on academic vocabulary instruction, including academic word lists which are specifically designed for K-12 are highly needed (Gardner & Davies, 2013; Graves, 2006). It seems that little evidence of the breadth of academic vocabulary learning has been dealt with in K-12. An outgrowth of this study, then, may be the extent to which academic vocabulary shows up throughout the K-12 world.
CHAPTER III
Developing the corpora: TUSC & SMACK

Introduction

As I explained in Chapter 2, using word lists have several benefits for ELLs in school contexts. In order to make a validated word list, it is essential to base the lexical data on a large representative corpus. Meanwhile, word lists provide data that can help vocabulary test developers in making new tests. Vocabulary tests that assess biased lexical data will lead to distorted results. Also, word lists can be beneficial in assessing the difficulty level of a text for ELLs. In the first step, therefore, it is important to create a corpus which is representative of the target domain and is derived from the learning purpose of K-12 ELLs. This chapter is built on these three pillars:

a) empirical examining language used in K-12 textbooks,

b) following the typology of words in creating the corpora with different purposes, and

c) using computer programs and software in compiling the corpora.

In Chapter 3, I review some main features in developing a corpus. Then, in Part 1, I explain the procedures for collecting textbooks, scanning and converting them into readable files for computer programs. LexTutor and AntConc software were used in the analysis of the lexical data. In Part 2 of Chapter 3, I delineate the method of developing the K-12 corpora: TUSC and SMACK. In the result section, I examine the statistical information of the corpora. I also report the coverage of STEM-related and academic words in each corpus.

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Research questions

As a review, I offer this reminder of the research questions:

1) What is the frequency distribution of vocabulary in U.S.-based K-12 textbooks?
   a) To what extent are
      i) K1 (1,000 most frequent words),
      ii) K2 (second 1,000 most frequent words),
      iii) academic words, and
      iv) off-list words
   represented in U.S.-based K-12 textbooks?

2) What are the most commonly used lemmas in U.S.-based K-12 textbooks?
   a) To what extent are
      (i) high-frequency,
      (ii) medium frequency, and
      (iii) low frequency lemmas,
      used in U.S.-based K-12 textbooks?
   b) What are the new academic and STEM-related word lists in U.S.-based K-12
      content area textbooks?

3) What is a new mobile app alongside a website to teach vocabulary and reading to
   ELLs as well as mainstream students?
TUSC and SMACK

For the purpose of answering the first three questions, I compiled two K-12 corpora, The Teacher’s U.S. Corpus (TUSC) and the Science and Math Academic Corpus for Kids SMACK (see later this chapter for a detailed description of the corpora).

Procedure for developing the corpora – TUSC and SMACK

Conrad (1996) believes that the goals of a research study should be reflected in the design of the corpus. The primary goal of the present dissertation is to make an academic core vocabulary list and a list of STEM-related words. In the next step, I focus on what is hopefully the most appropriate path through which such lists should be incorporated into technology to teach reading to ELLs. To this end, I adopted a corpus-driven approach in designing and developing the corpora with a focus on word lemma rather than inflectional and derivational variants of word families (see Chapter 2 for a detailed reason for choosing lemma as the unit of analysis).

Textbooks and materials were recruited from two sources, representing the K-12 textbooks of States of Florida and California. The four most populated states in the U.S., California, Texas, New York, and Florida, lead textbook decisions, and I initially hoped to compile a K-12 corpus representing all the four states. As a result of many limitations in recruiting and converting the textbooks, I created the corpus using the textbooks from California and Florida.

In my first step, I collected as many K-12 textbooks as possible from State of Florida, covering the subject domains of language arts, social studies, science, and math from all grades from kindergarten to twelfth grade. However, the grades are not equally
represented in textbooks. Then, I scanned the textbooks by using scanner machines and converted them into word document files with the ADOBE Reader Professional software. The recruiting, scanning and converting of Florida State textbooks were carried out over a period of more than two years from October 2014 to December 2016.

In the next step, I used the online library of CK-12 Foundation (www.ck12.com) to download the math and science textbooks of State of California. The content of the library is a free public domain and available for public use. The CK-12 Foundation was established in 2007 in California and is a non-profit organization whose mission is to facilitate the access to STEM education in the United States. During summer and fall of 2016, I converted the California State textbooks. After a meticulous analysis of a total of 122 textbooks from states of California and Florida, in the first stage of data coding, I filed the data into groups using subject matter and state. Then I ordered the total number of words (10,519,639) according to the frequency of lemmas alongside their inflectional and derivational forms. Through the remainder of this chapter, I will explain in details the procedures of developing TUSC and SMACK.

Table 1. Number of books and running words of Florida and California textbooks.

<table>
<thead>
<tr>
<th>States/ corpus</th>
<th>No. of books</th>
<th>No. of running words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida</td>
<td>49</td>
<td>3,298,508</td>
</tr>
<tr>
<td>California</td>
<td>73</td>
<td>7,272,551</td>
</tr>
<tr>
<td>TUSC</td>
<td>49</td>
<td>3,247,088</td>
</tr>
<tr>
<td>SMACK</td>
<td>102</td>
<td>8,522,864</td>
</tr>
</tbody>
</table>

10,571,059 (total words)
Main issues in developing a corpus

**Authenticity.** It is clear that the linguistic materials is the starting point in the field of corpus research. Johansson (1995) argues that corpus linguistics deals with authentic language or language in use. Therefore, the need for updating the educational corpora and word lists for the purpose of authentication is a significant task (Biber, 1994, Gardner & Davies, 2013).

Nation (2016) argues that there are two sources of authentic data that can be used for corpus research: written materials such as journal articles, newspapers, and textbooks. In this study, I use K-12 textbooks as the authentic materials that ELLs use in schools. Research (Nation & Webb, 2011) claims that K-12 textbooks is the main source through which ELLs receive academic words. Learner corpus (a corpus developed from learners’ language) is another source that is used in corpus-based research and its focus is mainly on discovering the structural problems in learners’ language.

**Sampling.** Biber (1994) claims that the most important issue in designing a corpus is defining the population for which the corpus is aimed to develop. In this way, the corpus will be also representative. Therefore, issues like the type of textbooks, the number of books at each level, the number of collected words are all sampling issues about which a corpus linguist should make a very clear decision before starting data collection.

**Academic and STEM-related corpora**

Sinclair (2005) argues that compiling a corpus founded on a principled foundation is the key idea behind the creation of any kind of corpus. To Sinclair, four core design principles of a corpus are 1) concepts that the corpus represents, 2) representativeness,
3) communicative purpose of the content, and 4) controlling the subject matter of the corpus by comparing it with other corpora. In addition, Flowerdew (2004) suggests a set of parameters that could be used to identify and classify specialized corpora:

1) Size of the corpus (a range of 1-5 million words are required)

2) A particular variety of English

3) Specialized purpose for the compilation of the corpus

4) Type of the text and topic of the subject matter

5) Context of the corpus (setting and communicative purpose).

As a result, Sinclair (2005) divides the continuum of corpus into general and specialized corpora. A general corpus is compiled to investigate language use and reveals the holistic patterns of language. The National British Corpus (NBC) and the Corpus of Contemporary American English (COCA) are examples of general corpora. A specialized corpus, however, is designed to describe a particular register or variety of language (Sinclair, 2001). A major difference with regard to design characteristics between general and specialized corpora is that specialized corpora are designed for early human intervention (EHI) research. However, general ones are compiled for delayed human intervention (DHI) studies (Sinclair, 2001). In the case of EHI, the compiler has a particular goal in mind and then creates a corpus accordingly, whereas in DHI the researcher does not have a particular goal in mind and patterns of the whole language is intended.

A specialized corpus (academic and STEM-related corpora in the case of the present dissertation) focuses on technical words which belongs to a special area of knowledge featured in the related word lists (Sinclair, 2005). Beyond the genre of the corpus, the proportion of subcorpora and the type of texts should also represent the kind of
language that ELLs meet in K-12 context. On average, the amount of reading for mainstream students varies but is under 100,000 tokens a year and about 2,000 tokens per day (Cunningham, 2005). Token is the number of words plus their repetitions. Therefore, this accounts for a small part of the language that they encounter and particularly the academic language that they receive (Nation, 2016). As a result, a corpus designed for ELLs should fill this gap and meet their school needs in K-12 contexts.

Table 2 represents seminal academic and STEM-related corpora since 2000. Table 1 also documents the text distribution with regard to Coxhead’s AWL across the seminal academic and STEM-related corpora developed since 2000. Among the 15 corpora, the corpora number 12, 14, and 15 (Coxhead, Stevens, & Tinkle, 2010; Dwyer & Ehsanzadeh, 2017; Ehsanzadeh & Dwyer, 2017) have been derived from K-12 textbooks. As shown in the table, the AWL, on average, covers 10% of most the written academic corpora. However, this number is 7.05 for Coxhead, Stevens, and Tinkle’s (2010) corpus of secondary school science textbooks. Surprisingly enough, the AWL’s coverage is 6.05 in Ehsanzadeh and Dwyer’s (2017) STEM-related corpus of California and Florida K-12 textbooks. This coverage again plunges down to 5.25 in Dwyer and Ehsanzadeh’s (2017) corpus of Florida K-12 textbooks, showing that there is a clear gap of about 5% in regard to academic vocabulary coverage between K-12 textbooks and texts written for adults at college level.

Both corpora are written and there is no sample of spoken language data in regard to the K-12 context. As a result, the domain of research questions is limited to the word knowledge that ELLs need for reading comprehension, in other words, written receptive
vocabulary knowledge. All the research questions of this dissertation study are answered in chapters 4, 5, and 6, accordingly.
<table>
<thead>
<tr>
<th>Study</th>
<th>Corpus genre</th>
<th># of words</th>
<th>WAL Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Cobb &amp; Horst (2004)</td>
<td>Learned section of Brown Corpus</td>
<td>14,283</td>
<td>11.6</td>
</tr>
<tr>
<td>3-Hyland &amp; Tse (2007)</td>
<td>Sciences, engineering, &amp; social sciences</td>
<td>3,292,600</td>
<td>10.6</td>
</tr>
<tr>
<td>4-Chen &amp; Ge (2007)</td>
<td>Medical texts</td>
<td>190,425</td>
<td>10.073</td>
</tr>
<tr>
<td>5-Konstantakis (2007)</td>
<td>Business texts</td>
<td>1 million</td>
<td>11.51</td>
</tr>
<tr>
<td>6-Coxhead &amp; Hirsh (2007)</td>
<td>Science texts</td>
<td>1.5 million</td>
<td>8.96</td>
</tr>
<tr>
<td>7-Dwyer (2005)</td>
<td>Florida K-12 textbooks</td>
<td>156,000</td>
<td>3.97</td>
</tr>
<tr>
<td>8-Ward (2009)</td>
<td>Engineering texts</td>
<td>271,000</td>
<td>11.3</td>
</tr>
<tr>
<td>9-Martinez, Beck, &amp; Panza (2009)</td>
<td>Agricultural texts</td>
<td>826,416</td>
<td>9.06</td>
</tr>
<tr>
<td>11-Li &amp; Qian (2010)</td>
<td>Finance</td>
<td>6.3 million</td>
<td>10.46</td>
</tr>
<tr>
<td>12-Coxhead, Stevens, &amp; Tinkle (2010)</td>
<td>Pathway series of secondary science textbooks</td>
<td>279,733</td>
<td>7.05</td>
</tr>
<tr>
<td>13-Davies &amp; Gardner (2013)</td>
<td>Academic journals, humanities, &amp; education</td>
<td>120 million</td>
<td>Not reported</td>
</tr>
<tr>
<td>14-Dwyer &amp; Ehsanzadeh (2017)</td>
<td>Florida K-12 textbooks</td>
<td>3,298,508</td>
<td>5.25</td>
</tr>
<tr>
<td>15-Ehsanzadeh &amp; Dwyer (2017)</td>
<td>California K-12 math &amp; science textbooks</td>
<td>8,522,864</td>
<td>6.05</td>
</tr>
</tbody>
</table>
Research question 1

The first research question focuses on the coverage distribution of Cobb’s (2017) word classification (see Chapter 2) across K-12 textbooks. The academic vocabulary knowledge in this classification follows Coxhead’s (2000) AWL. K1 and K2 (first and second most common words) represent the extent to which words in K-12 books are from first 1,000 (K1) most frequent words or the second 1,000 (K2). Having a clear picture of these categories in K-12 textbooks will be an invaluable guide in designing supplementary materials. Here is the first question:

1) What is the vocabulary frequency distribution based on Cobb’s (2017) classification in U.S.-based K-12 textbooks?

   a) To what extent are

      (i) K1 (first one thousand most frequent words),

      (ii) K2 (second one thousand most frequent words),

      (iii) academic words, and

      (iv) off-list words

   represented in U.S.-based K-12 textbooks?

Analysis software used for developing the corpora

LexTutor

LexTutor (www.lextutor.ca) is a vocabulary search tool. It is a complex and powerful web-based engine designed by Tom Cobb in late 1990s. He developed and has maintained the page since 1990s. The page has three main entries: tutorial, research, and teachers. The research section is where a student can begin his data analysis. The tutorial
section provides the learner with interactive tools for self-directed learning, and teachers section is a source of classroom activities for teachers.

Vocab profile (VP) is the subsection of LexTutor that I have often used in making my initial word lists for the Florida textbooks. Vocab profile accepts files in rtf format and has a limited analysis capacity of no more than 30,000 words at a time. Vocab profile produces a statistical table of four tiers of vocabulary, namely as: K1 (1-1,000 most frequent words), K2 (1,001-2,000 most frequent words), AWL (a list of academic words mostly derived from Coxhead’s AWL), and Off-list (words not appeared in any of these three tiers). Vocab profile is a versatile tool for evaluating the text difficulty. It can also be used for reviewing the core vocabulary.

**AntConc (version 3.5.2.)**

AntConc (Anthony, 2017) is a multiplatform software developed to conduct research in corpus linguistics and analyze corpus-driven data. The software may be run on both Microsoft Windows and Macintosh. To produce executables for a variety of operating systems, AntConc was developed in Perl, using different compilers.

AntConc is a versatile software with seven main analysis tools:

1. Concordance Tool (which analyzes the text and gives the results in a KWIC, Key Word In Context),
2. Concordance Plot Tool (which searches the text and gives the results in a barcode format or plotted), File View Tool (gives the results of the text in individual files),
3. Clusters/N-Grams (which scans the whole corpus and then gives the results produced in the Concordance Tool or Concordance Plot Tool and the main feature of this tool is that it allows the researcher to find common expressions and words in a corpus),

4. Collocates Tool (which gives collocates and allows to examine the non-sequential patterns in a corpus),

5. Word List (which allows the researcher to find the most frequent words in a corpus and I used it for the analysis of frequency distribution of lemma in research question 2, and

6. Keyword List (which compares the frequency distribution of words in the corpus with a target corpus).

**Results**

For the result of this chapter, I answer the first research question which asks about a classification of K-12 textbooks in terms of Tom Cobb’s first and second thousand most common words plus academic vocabulary. The research question is in line with Cobb’s classification in the K-12 context in USA. With respect to the classification of vocabulary in this study and the definition of academic and STEM words, I used AntConc software. Academic words are words that appear commonly in three out of four content areas (math, language arts, science, and social studies). Therefore, I extracted all common words in three content areas by the use of the software and label them academic words in AntConc. STEM words, however, are domain-specific words appearing mainly in one of the four
content areas (see Chapter 4 for a complete list of academic and STEM-related words in this study).

Teachers’ U.S. Corpus – TUSC

The Teachers’ U.S. Corpus (TUSC) is the corpus of Florida State textbooks which contains 49 books. Teachers’ U.S. Corpus is a general-purpose corpus representing all four K-12 content areas (language arts, math, science, and social studies). As a result of the heavy burden of recruiting textbooks and other related limitations that I had, TUSC is skewed towards middle school textbooks. With regard to the content area, TUSC represents more language arts and social studies. Table 3 gives more information about TUSC. The distinction of books is based on K-12 content areas.

Table 3. An overview of TUSC.

<table>
<thead>
<tr>
<th>Content area</th>
<th>No. of books</th>
<th>No. of running words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math</td>
<td>15</td>
<td>741,950</td>
</tr>
<tr>
<td>Science</td>
<td>14</td>
<td>559,783</td>
</tr>
<tr>
<td>Social Studies</td>
<td>9</td>
<td>951,338</td>
</tr>
<tr>
<td>Lang Arts</td>
<td>11</td>
<td>1,045,437</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,298,508 (total)</td>
</tr>
</tbody>
</table>

Tables 4 and 5 give detailed information regarding the number of words in four tiers of word frequency according to LexTutor in the subject matter of Language Arts and Social Studies. I divided the textbooks in these content areas (11 textbooks in Language Arts and
nine textbooks in Social Studies) into four grade groups, namely as K-2, 3-5, 6-8, and 9-12.

The total number of words in Language Arts and Social Studies is 1,996,775.

Table 4. Language Arts in TUSC.

<table>
<thead>
<tr>
<th>Lang &amp; Arts (11 books)</th>
<th>AWL</th>
<th>K1</th>
<th>K2</th>
<th>OFF-LIST</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-2 (1 book)</td>
<td>290</td>
<td>14,942</td>
<td>1,632</td>
<td>864</td>
</tr>
<tr>
<td>3-5 (3 books)</td>
<td>4,261</td>
<td>87,331</td>
<td>7,046</td>
<td>4,017</td>
</tr>
<tr>
<td>6-8 (4 books)</td>
<td>3,756</td>
<td>91,113</td>
<td>7,504</td>
<td>8,531</td>
</tr>
<tr>
<td>9-12 (3 books)</td>
<td>37,062</td>
<td>698,929</td>
<td>56,038</td>
<td>22,137</td>
</tr>
</tbody>
</table>

Lang. Arts total: 45,371 (4.33%) 892,315 (85.35%) 72,220 (6.90%) 35,531 (3.39%)

Total words: 1,045,437

Table 5. Social Studies in TUSC.

<table>
<thead>
<tr>
<th>Social Studies (9 books)</th>
<th>AWL</th>
<th>K1</th>
<th>K2</th>
<th>OFF-LIST</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-2 (1 book)</td>
<td>575</td>
<td>16,438</td>
<td>1,167</td>
<td>1,392</td>
</tr>
<tr>
<td>3-5 (3 books)</td>
<td>3,860</td>
<td>65,004</td>
<td>4,819</td>
<td>2,431</td>
</tr>
<tr>
<td>6-8 (3 books)</td>
<td>8,191</td>
<td>127,124</td>
<td>8,026</td>
<td>3,612</td>
</tr>
<tr>
<td>9-12 (2 books)</td>
<td>53,318</td>
<td>591,427</td>
<td>37,440</td>
<td>26,514</td>
</tr>
</tbody>
</table>

Social total: 65,944 (6.93%) 799,993 (84.09%) 51,452 (5.40%) 33,949 (3.56%)

Total words: 951,338
Tables 6 and 7 represent STEM-related domain of TUSC with a total of 29 textbooks (15 Math and 14 Science textbooks) and a total number of 1,250,268 words. As could be seen in Table 6 and 7, Math is more intense than Science in terms of academic language. Surprisingly enough, Science has the least intensive academic language among the four content areas in Florida school system. Figure 2 shows the academic vocabulary trend in TUSC across four content area.

Table 6. Math in TUSC.

<table>
<thead>
<tr>
<th>Math</th>
<th>AWL</th>
<th>K1</th>
<th>K2</th>
<th>OFF-LIST</th>
</tr>
</thead>
<tbody>
<tr>
<td>(15 books)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-2 (1 book)</td>
<td>1,885</td>
<td>58,452</td>
<td>4,269</td>
<td>3,006</td>
</tr>
<tr>
<td>3-5 (3 books)</td>
<td>3,217</td>
<td>99,912</td>
<td>8,423</td>
<td>1,418</td>
</tr>
<tr>
<td>6-8 (6 books)</td>
<td>15,736</td>
<td>282,612</td>
<td>17,254</td>
<td>4,901</td>
</tr>
<tr>
<td>9-12 (5 books)</td>
<td>13,171</td>
<td>213,926</td>
<td>10,107</td>
<td>3,661</td>
</tr>
<tr>
<td>Math total:</td>
<td>34,009 (4.58%)</td>
<td>654,902 (88.26%)</td>
<td>40,053 (5.39%)</td>
<td>12,986 (1.75%)</td>
</tr>
<tr>
<td>Total words:</td>
<td>741,950</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7. Science in TUSC.

<table>
<thead>
<tr>
<th>Science (14 books)</th>
<th>AWL</th>
<th>K1</th>
<th>K2</th>
<th>OFF-LIST</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-2 (1 book)</td>
<td>1,267</td>
<td>50,506</td>
<td>4,775</td>
<td>2,616</td>
</tr>
<tr>
<td>3-5 (3 books)</td>
<td>3,901</td>
<td>82,713</td>
<td>8,240</td>
<td>10,366</td>
</tr>
<tr>
<td>6-8 (7 books)</td>
<td>13,327</td>
<td>201,843</td>
<td>19,271</td>
<td>30,971</td>
</tr>
<tr>
<td>9-12 (3 books)</td>
<td>8,771</td>
<td>98,283</td>
<td>9,122</td>
<td>13,811</td>
</tr>
<tr>
<td>Science total:</td>
<td>27,266 (4.87%)</td>
<td>433,345 (77.41%)</td>
<td>41,408 (7.39%)</td>
<td>57,764 (10.31%)</td>
</tr>
<tr>
<td>(559,783)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Academic words in TUSC.
Science/ Math Corpus for K-12 Kids – SMACK

The Science/Math Corpus for K-12 Kids (SMACK) is a STEM-related corpus containing 102 books from States of California and Florida with only 29 books from Florida and 73 from California. The Science/Math Corpus for K-12 Kids is a corpus of middle and high school textbooks. In sampling the corpus, I attempted to choose the books from a wide range of STEM-related subject areas to make SMACK as representative as possible. The Science/Math Corpus for K-12 Kids includes the following subjects from school math and science domains: Math (15 books), Algebra (12 books), Analysis (2 books), Calculus (3 books), Geometry (8 books), Probability (6 books), Trigonometry (2 books), Astronomy (1 book), Biology (14 books), Chemistry (3 books), Earth science (4 books), Engineering (3 books), Science (19 books), Life science (2 books), Physical science (2 books), Physics (5 books), and Technology (1 book). All the textbooks are written for K-12 U.S. mainstream students.

Table 8. Composition of SMACK.

<table>
<thead>
<tr>
<th>Content area</th>
<th>Math</th>
<th>Science</th>
<th>SMACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total text token</td>
<td>4,547,909</td>
<td>3,974,955</td>
<td>8,522,864 Words</td>
</tr>
<tr>
<td>Number of books</td>
<td>48</td>
<td>54</td>
<td>102 Books</td>
</tr>
<tr>
<td>Subject areas</td>
<td>Math</td>
<td>Analysis</td>
<td>Biology</td>
</tr>
<tr>
<td></td>
<td>Algebra</td>
<td>Calculus</td>
<td>Chemistry</td>
</tr>
<tr>
<td></td>
<td>Geometry</td>
<td>Probability</td>
<td>Earth science</td>
</tr>
<tr>
<td></td>
<td>Trigonometry</td>
<td></td>
<td>Engineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Life science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Physical science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Physics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&amp; Technology</td>
</tr>
</tbody>
</table>
When it comes to academic vocabulary in STEM-related domain in school textbooks, Math seems to be more intense than Science. As seen in Figure 4, the academic vocabulary in both Math and Science is less than 10%. Though, there is no surprise that SMACK is richer than TUSC with respect to academic vocabulary.

Figure 4. Academic vocabulary in SMACK.
Figure 5. STEM words in TUSC and SMACK.
CHAPTER IV

The word lists

Introduction

Research question

The main research question that I will answer in Chapter 4 is the second one of the study through which I will develop three frequency word lists, one academic and STEM-related, as well.

2) What are the most commonly used lemmas in U.S.-based K-12 textbooks?

b) To what extent are
   i) high-frequency,
   ii) medium frequency, and
   iii) low frequency lemmas,
   used in U.S.-based K-12 textbooks?

b) What are the new academic and STEM-related word lists in U.S.-based K-12 content area textbooks?

As discussed in Chapter 2, incorporating word lists can offer many advantages into our second language classes. Gardner and Davies (2013) suggest that developing specialized word lists can be an essential step toward shortening the learning time and teaching ELLs words that they need for a particular purpose. For younger learners, such may be based on a corpus that reflects K-12 domains. Simultaneously, frequency rankings that consider dispersion seem to be an appropriate manner of learning vocabulary (Nation, 2013).
Over the past decade, various word list have been developed for teaching academic and core vocabulary (see Chapter 3 for a detailed review). These lists (AWL, ALV, and UWL), however, have faced critique (see Chapter 2). To achieve the teaching implications and purposes mentioned above and earlier in this dissertation for teaching reading through a color-coded system, as featured in LexTutor, and making vocabulary instruction more efficient, I developed five word lists, namely three frequency lists (high, mid, low), academic, and STEM-related word lists to answer the second research question.

Chapter 4 is divided into two parts. In Part 1, I review the procedure and main techniques for making a word list. The guideline developed by Nation and Webb (2011) and Nation (2016) are also reviewed in the next step. A significant section in this part is the examination of what should be included in the word lists. I also give some examples showing the main pattern of the set criteria. Part 2 is the explanation of the validating method of the word lists and the final products as the word lists. The text coverage method is used to examine the validity of each word list.

**Procedure for making a word list**

Considering the proposed research questions for the present dissertation, a corpus-driven approach was selected as an appropriate model. In this dissertation, I followed text analysis design to develop and validate the word lists. Text analysis is not the same as content analysis design, whose focus is on linguistic properties and is mostly used in corpus-based research studies.
Nation and Webb (2011) and Nation (2016) are principal sources who explain how to make word lists and validate them. Nation and Webb argue that creating an effective word list includes the following steps:

1. We should have a good reason for making a word list as well as appropriate research questions.
2. The unit of counting is the next important decision that a researcher should make before embarking the word selection process. As I explained in Chapter 2, the counting unit for this dissertation is lemma.
3. A corpus should be compiled according to the needs of the people who will use the word list. The makeup of the corpus should be representative and large enough to have an acceptable text coverage. In regard with the size of the corpus, Brysbaert and New (2009) believe that a corpus of 1,000,000 running words is acceptable for high frequency words. For low frequency words, however, at least 30,000,000 tokens will be an acceptable size of the corpus.
4. Decisions regarding definitions of a words, as well as word types, and which ones should be counted as a word to be included in the corpus should be considerations. For example, should propositions or proper nouns be included in the corpus?
5. The criteria for ordering the words in the word list are an important issues that shape the form of the final product. There do exist frequency-based word lists (Campion & Elley, 1971; Praninskas, 1972; Lynn, 1973; Ghadessy, 1979). Therefore, the decision about how to order words on the list based on whether frequency or dispersion is a critical issue in making a word list.
6. Word lists should be examined against other independent corpora or word lists to check whether there may be any improper placement of words in a wrong list.

As mentioned in Chapter 2, there are many word lists in different languages, and most of them are frequency-based lists (BLI, 1986; Eaton, 1940; Juillard, Brodin, & Davidovitch, 1970; Juillard & Chang-Rodrigues, 1964; NLRI, 1962, 2006; Thorndike & Lorge, 1944; Xiao, Rayson, & McEnery, 2009). Additionally, some guidelines have been prepared on how to use or adjust these word lists (Gries, 2008; 2010). Most guidelines, however, explain procedures on how the word lists were made and argue for their validity and reliability. Particular issues with regard to word lists, including how they should be developed and validated alongside the teaching implications, have been extensively discussed in Nation and Webb (2011) and Nation (2016) which are the guidelines used in developing and validating the word lists for this study. Of the six steps involved in making and validating word lists, three of them—unit of counting, criteria for counting words and separate lists, and criteria for ordering words—are explained in further detail:

**Unit of counting**

The three main units of counting for designing a word list are word type, lemma, and word family (Nation, 2016). A good example of word type as the unit of counting is Carroll, Davies, and Richman’s (1971) study. Leech, Rayson, and Wilson (2001), however, used lemma as the unit of counting and it only considers inflections. In another study, Vermeer (2004) also applied lemma as the unit of counting to assess productive knowledge. For the purpose of this study, I will use lemma as the unit of counting. To count receptive knowledge, a word family, which is an inclusive unit of counting is the best option (Nation
When a learner knows one or two members of a word family, little learning burden will be needed to use other family members receptively in reading comprehension. For example, if a learner knows the word *accesses*, understanding *accessed, accessible, accessibility*, or *inaccessible* and *inaccessibility* will not be difficult tasks for the learner. Many word lists have been developed with the word family as the unit of counting. Nation’s (2004) word list developed from British National Corpus is a good example of this type.

With regard to derivational and inflectional forms, the main issue with this unit of counting is that it is difficult to be consistent about which forms should be included under a headword. However, it stands clear that all forms that require little learning should go under the related word family.

Another important issue with respect to counting is the concept of *multiword*, which is a sequence of two or three words like *in spite of* and *so that*. In this regard, Leech, Rayson, and Wilson (2001) argue that multiwords should be counted as single words, because in English grammar they are considered single words. Nation and Webb (2011) believe that learning of multiwords requires additional learning effort because these words do not have transparent meanings and learners should guess their meanings. However, a main problem with regard to multiword units is the lack of unified and consistent judgment about which words should be counted as a multiword. When it comes to a large-scale corpus, it would not be a feasible task for a researcher to go through it manually. Even if they are considered as single words, an additional problem would be counting the frequency of each of the components of a multiword. Without using a proper computer program, this would be a very tedious and time consuming task.
Criteria for counting words and separate lists

Nation (2016) argues that the learning burden principle (see Chapter 1 for more details) determines whether a word should be considered as a headword. In other words, if a learner does not need previous knowledge to learn the meaning of a form (e.g., proper nouns), or if the learner can construct the meaning from previous knowledge (e.g., derivational and inflectional forms), then this form of the word should not be considered as a headword in the word list. As a result, Nation and Webb (2011) and Nation (2016) decided to look for non-words, proper names, abbreviations, marginal words (e.g., *eh*), homonyms and homographs (e.g., *sow*), transparent compounds (e.g., *lifespan*), foreign words (e.g., *précis*) to make a separate word list for these items. Nation (2016) believes that separate word lists are invaluable educational tools that allow learners to read what they need and make adjustments without referring to other word lists.

Criteria for ordering words

A main goal of this research study is to show what the best order of learning vocabulary should be for ELLs in K-12 context. In this regard, the criteria for ordering words, which is mostly applied for frequency word lists, will guide us in ordering the words. Nation and Webb (2011) and Nation (2016) argue, simply, that the best criterion is that the more words learners know, the more effective reading will be.

The implication, however, can be monumental with respect to list development: that a higher text coverage will certainly lead to a stronger chance for reading comprehension. Therefore, frequency is an important criterion for deciding what the most efficient word learning order may be. The question arising then is how frequency should
be measured. Nation (2016) believes that compiling a corpus for each learner and then checking the frequency of each word would be the best strategy that suits the learners’ needs. Creating a means for each person to develop their own word list ahead of their learning may be a valuable goal but is beyond the scope of this study. However, it may be more immediately possible to categorize the needs of learners and then create a corpus for each category of needs.

**How to count words for inclusion in a word list**

Among the first decisions that a researcher should make before taking any step in developing a word list is the decision about which words should be included in the word list as the final product. This decision itself is a complicated one that would no doubt affect the nature and quality of a word list. For example, do digits like 12 and 1397 showing up in math textbooks count as words? What about abbreviations like Max, Min, or HQ that appear in science textbooks? Do forms mixing numbers and letters like Apollo13 or P3.4 showing up in math and science books count as separate words?

In sections below, I address these questions and other issues related to how to deal with what should be counted as a word and included in the word lists that I am developing in this study. Also, I will explain the rules and regulations that I applied in deciding whether a particular word should be included or not.

**Assumed known words**

*Assumed known words* (Nation & Webb, 2011) are specific nouns and/or proper names, including geographical places and historical nouns, that require very little or no
background knowledge to be understood in reading a text passage. Nation and Webb (2011) argue that whether a word should be counted in a list is mainly based on the degree to which the word contributes to the principle of learning burden (see Chapter 1 for definition of learning burden). Accordingly, Nation (2006) created separated word lists for known words of compounds and proper nouns. Since a goal of this dissertation is to establish lists that address learning burden, I did not include known words in the final word lists.

**Homoforms**

Lexicographers (Gardner, 2013; Nation, 2016) define homonyms as words that have the same spoken and written form but with different meanings (for example, bridge, miss, rest). Homographs, however, are words that have different spoken form with unrelated meanings that have the same written form (for example, lead, present, row). Also, homophones are words with the same oral form but with different written form and meaning (for example, eye/I, peace/piece). To put these three types under one platform, Nation (2016, p. 41) uses the term homoform. Homoforms (all three types) are the linguistic features that are common and pervasive in any language including English. As a result, having a clear thought and well-decided approach towards the inclusion policy of homoforms in the word list is among the very first steps.
Table 9. Three categories of homoform.

<table>
<thead>
<tr>
<th></th>
<th>Written form</th>
<th>Spoken form</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homograph</td>
<td>same</td>
<td>different</td>
<td>different</td>
<td>lead, minute, row</td>
</tr>
<tr>
<td>Homonym</td>
<td>same</td>
<td>same</td>
<td>different</td>
<td>case, miss, rest</td>
</tr>
<tr>
<td>Homophone</td>
<td>different</td>
<td>same</td>
<td>different</td>
<td>peace/piece write/right</td>
</tr>
</tbody>
</table>

In an analysis of homoforms included in word lists, Wang and Nation (2004) reported that Coxhead’s AWL has 60 homographs and homonyms (for example, decline, issue, volume). Considering the fact that AWL has 570 word families, it means that approximately one tenth (one word in every ten word family) contains a homoform. This further demonstrates that all three types of homoforms would have a considerable effect on the total number of entries in a word list. Because homophones have exactly the same written forms, they are usually put under different entries in written corpora. This would consequently increase the number of items in a word list. Nation (2016) argues that homonyms and homographs should be counted as two different lemmas, especially when the word list maker is interested in teaching and learning vocabulary in a second language, because each form of homograph or homonym has a different meaning and requires learning a new concept or recognizing one form with different meanings. One further issue here is the frequency of occurrence of pairs of homographs and homophones with one member of the pair has a much higher frequency compared to the other members. According to what I discussed in this section, I use different forms of homonyms and homographs as different items in my word lists.
Table 10. Examples of homoform in K-12 corpus.

<table>
<thead>
<tr>
<th>Homoform</th>
<th>Freq.</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar</td>
<td>201</td>
<td>pub, to exclude, bar exam, beam of steel</td>
</tr>
<tr>
<td>Charge</td>
<td>1094</td>
<td>officially accuse of crime, electrical charge, a rushing attach</td>
</tr>
<tr>
<td>Coast</td>
<td>598</td>
<td>coastline, move easily, not work hard</td>
</tr>
<tr>
<td>Country</td>
<td>2098</td>
<td>far from city, nation</td>
</tr>
<tr>
<td>Date</td>
<td>680</td>
<td>to see romantically, someone’s age, a fruit</td>
</tr>
<tr>
<td>Fall</td>
<td>1023</td>
<td>autumn, to descend</td>
</tr>
<tr>
<td>Just</td>
<td>310</td>
<td>only, fair</td>
</tr>
<tr>
<td>Kind</td>
<td>3019</td>
<td>gentle, a class</td>
</tr>
<tr>
<td>Nature</td>
<td>4012</td>
<td>the natural world, inherent quality</td>
</tr>
<tr>
<td>Park</td>
<td>1029</td>
<td>public area, to bring a car to a halt</td>
</tr>
<tr>
<td>Passage</td>
<td>2027</td>
<td>travel, a passageway, passing (a law)</td>
</tr>
<tr>
<td>Patient</td>
<td>198</td>
<td>a doctor’s client, to have patience</td>
</tr>
<tr>
<td>Second</td>
<td>5210</td>
<td>related to time, after the first</td>
</tr>
<tr>
<td>Stage</td>
<td>2013</td>
<td>a place for actors, a part of development</td>
</tr>
</tbody>
</table>
Some corpus linguists and word list makers (Biemiller, 2010) took a step further, distinguishing members of homoforms by claiming that related senses of one word should be distinguished and counted as different words in a word list. For example, *court in court of appeal* should be seen as a different word from *appeal* relating to a *request*. In favor of this argument, Nation (2016) believes that different senses of a word might be translated using different words in a foreign language; therefore, for word lists developed for the purpose of teaching vocabulary in another language, including the ones that I am making through this dissertation, this could be a reasonable idea. However, Nation further argues that distinguishing different senses of one word will not help ELLs apply contextual clues while reading and therefore should not be used separately in a word list.

**Proper nouns**

In written English, *proper nouns and names* are usually identified by their first letter being capitalized; however, not every capitalized word is a proper noun. It seems that proper nouns are straightforward, but they have complications as well. For example, the first word of a sentence is capitalized and this should be distinguished from a proper noun in a word list. A further issue is that there is not consistency in the use of capitalization for some proper nouns like the game *Monopoly* is capitalized while *chess* is not.

The main feature of proper nouns is that they do not contribute to the comprehension of the text as they do not carry the key meaning beyond the meaning of the thing that they refer to. In this respect, Nation (2016) argues that ELLs require very little previous knowledge to learn some of proper nouns. According to National British Corpus (2018), the names of geographical and historical places, personal names including the
names of famous people, and enterprises account for the biggest part of proper nouns in written texts. An important part of this category of proper nouns is the names of festivals and events, including wars, hurricanes, sporting events, and TV shows (Kobeleva, 2008). However, not every proper noun needs previous knowledge in order to be understood. Nagy and Anderson (1984) argue that there might be approximately 1000 of these proper nouns that you need to have a background knowledge to understand them in a sentence. These sentence are good examples of these proper nouns: “He is not Einstein. He is not another Gandhi.” As a result, Nation (2016) argues that a list of such proper nouns will help improve ELLs reading and literacy because they entail stable meanings that ELLs need to learn. Some of these words are even unknown to mainstream students.
Unlike the idea that most teachers think proper nouns do not create problems for ELLs in reading comprehension, Brown (2012) argues that this is not true. Similarly, Kobeleva (2012) reported that in a listening comprehension test of news texts, having previous knowledge of proper nouns improves the ELLs’ comprehension significantly.

Nation and Webb (2011) carried out a careful analysis, focusing on words not included in the National British Corpus. They reported that almost half of the words not

<table>
<thead>
<tr>
<th>Idiom or phrase</th>
<th>frequency</th>
<th>word list type</th>
</tr>
</thead>
<tbody>
<tr>
<td>America</td>
<td>2013</td>
<td>high freq.</td>
</tr>
<tr>
<td>April</td>
<td>48</td>
<td>mid freq.</td>
</tr>
<tr>
<td>Bishop</td>
<td>26</td>
<td>mid freq.</td>
</tr>
<tr>
<td>Britain</td>
<td>109</td>
<td>high freq.</td>
</tr>
<tr>
<td>Europe</td>
<td>173</td>
<td>high freq.</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>6</td>
<td>low freq.</td>
</tr>
<tr>
<td>King</td>
<td>938</td>
<td>high freq.</td>
</tr>
<tr>
<td>New York</td>
<td>61</td>
<td>high freq.</td>
</tr>
<tr>
<td>Obama</td>
<td>23</td>
<td>mid freq.</td>
</tr>
<tr>
<td>Saturday</td>
<td>83</td>
<td>high freq.</td>
</tr>
<tr>
<td>South America</td>
<td>79</td>
<td>high freq.</td>
</tr>
<tr>
<td>White House</td>
<td>103</td>
<td>high freq.</td>
</tr>
</tbody>
</table>
appearing in BNC/COCA were proper nouns. Fortunately, all proper nouns in English are distinguishable through AntConc WordProfiler (a free software I used for the purpose of text analysis in this dissertation) by using lists of proper nouns that have been uploaded into the software.

**Compounds and hyphenated words**

Hyphenated words are two words joined together with a hyphen (for example, life-span, wife-less, long-term). Nation (2013) argues that the main reason for using a hyphen is to show that the two words are closely related. Interestingly enough, we have more than 10,000 hyphenated words with a frequency of at least 2 or higher in BNC.

A main issue in dealing with hyphenated words in developing a word list is a lack of consistency in the form of compound words. Sometime they appear with a hyphen (e.g., *short-term*), sometimes they appear without a hyphen (*shortterm*), and also in some cases they occur as spaced compound words (*short term*). Therefore, Nation (2016) argues that compound words shouldn’t be taken as a grammatical category of items because there are three variations in whether they are written as two separated words, or with no space, or even as a hyphenated word. As a result, this makes the decision about how to include them in word lists very complicated. For example, *lifespan, railway, shareholder* are the compound words that have both hyphenated and non-hyphenated forms in BNC but with a considerable difference in terms of frequency between the two forms.
Table 12. A sample of hyphenated words in the five word lists in this study.

<table>
<thead>
<tr>
<th>Idiom or phrase</th>
<th>frequency</th>
<th>word list type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-time</td>
<td>51</td>
<td>mid freq.</td>
</tr>
<tr>
<td>Large-scale</td>
<td>29</td>
<td>mid freq.</td>
</tr>
<tr>
<td>long-term</td>
<td>108</td>
<td>high freq.</td>
</tr>
<tr>
<td>middle-class</td>
<td>118</td>
<td>high freq.</td>
</tr>
<tr>
<td>part-time</td>
<td>23</td>
<td>high freq.</td>
</tr>
<tr>
<td>video-taped</td>
<td>41</td>
<td>high freq.</td>
</tr>
<tr>
<td>short-term</td>
<td>81</td>
<td>mid freq.</td>
</tr>
<tr>
<td>so-called</td>
<td>211</td>
<td>high freq.</td>
</tr>
<tr>
<td>vice-president</td>
<td>15</td>
<td>mid freq.</td>
</tr>
<tr>
<td>well-known</td>
<td>1723</td>
<td>high freq.</td>
</tr>
</tbody>
</table>

As a solution in counting compound words, Brysbaert, Stevens, Mandera and Keuleers (2016) split all the compound words that they collected in their corpus into their parts and count each component as a separate word so that their occurrences are counted separately. However, one problem to this approach is making a decision about which family the compound words should be counted under. For example, should we count weekend under end or week? Another issue is that it will misrepresent the frequency of weekend if we ignore the frequency of one component, for example, end in weekend. In this dissertation, I used compound nouns as a single word without hyphen or space with a separate frequency in the word lists. As a valuable source of compound nouns for making
a word list, the Range and AntWordProfile programs have a list of more than 3,000 compound words, with about two members for each family. This list accounts for 0.1% of the text types and 0.36% of the text tokens in BNC.

**Idiomatic and phrasal expressions**

Idioms and phrases are a group of words that come together frequently. They are also called formulaic sequences or lexical bundles. The main issue with regard to making a word list for ELLs and considering idiomatic expressions is coming up with a clear definition of what should be counted as an idiom and how to apply it consistently across the whole corpus (Nation, 2016). In order to decide about the inclusion of such expressions in a word list, Nation (2016) claims that we should consider these factors: 1) number of components of the expression, 2) discontinuity and adjacency of the components in the expression, 3) being grammatically fixed or variable, and 4) being capable of using lexically variable items.

Shin and Nation (2008) found that frequent idioms and phrases tend to be shorter than less frequent ones. They further claimed that the frequency of idiomatic expressions follow Zipf’s law (see Chapter 1 for definition of this law) in that they tend to be more economic in terms of components. According to the nature of the K-12 corpora in this dissertation, there is not a high number of idiomatic expressions in the corpora, and I included most of the expressions in the high frequency word list.
Table 13. Examples of idiomatic and phrasal expressions.

<table>
<thead>
<tr>
<th>Idiom or phrase</th>
<th>Freq.</th>
<th>Word list type</th>
</tr>
</thead>
<tbody>
<tr>
<td>a bit</td>
<td>1091</td>
<td>high freq.</td>
</tr>
<tr>
<td>as a result</td>
<td>1230</td>
<td>high freq.</td>
</tr>
<tr>
<td>as well</td>
<td>901</td>
<td>high freq.</td>
</tr>
<tr>
<td>by and large</td>
<td>219</td>
<td>high freq.</td>
</tr>
<tr>
<td>for instance</td>
<td>711</td>
<td>high freq.</td>
</tr>
<tr>
<td>in addition to</td>
<td>315</td>
<td>high freq.</td>
</tr>
<tr>
<td>on the other hand</td>
<td>211</td>
<td>high freq.</td>
</tr>
<tr>
<td>out of hand</td>
<td>124</td>
<td>high freq.</td>
</tr>
<tr>
<td>pulling your leg</td>
<td>1</td>
<td>low freq.</td>
</tr>
<tr>
<td>the Big Apple</td>
<td>3</td>
<td>low freq.</td>
</tr>
</tbody>
</table>

**Acronyms and abbreviations**

An acronym is a word made of a group of letters that each is the first letter of a word. Acronyms and abbreviations usually do not contribute toward the core meaning of a text and consequently do not carry the significant meaning. Many acronyms refer to a unique entity and therefore they could be taken as proper nouns. Nation (2016) argues that acronyms that are a reduced form of a word (Rd for Road) should go under the items of that word family. When an acronym is used very often and is also easy to pronounce, it could stand as an independent word, for example, NASA and laser. In order to be included in a word list, Nation (2016) argues that 1) acronyms should be made of the first letters of
a series of words, 2) all the words should be known by adult native speakers, and 3) the pronunciation of the acronym should sound out the letters (MIT), or pronounce it as a word (UNESCO). Below is a list of most frequent acronyms (above 2,000 frequency in BNC) that are considered high frequency words in the word lists in this study.

One argument in favor of having a separate list of acronyms (Nation and Webb, 2011) is that they are made of a series of words that are usually known and a separate list of acronyms will be helpful in improving the ELLs’ receptive knowledge. However, another argument against the inclusion of acronyms is that such a list will be confusing without coming alongside homonymy words (Nation, 2016).
Table 14. Sample acronyms in the word lists.

<table>
<thead>
<tr>
<th>Word</th>
<th>Freq.</th>
<th>Word list type</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g.</td>
<td>128</td>
<td>high freq.</td>
</tr>
<tr>
<td>CD</td>
<td>23</td>
<td>mid freq.</td>
</tr>
<tr>
<td>DC</td>
<td>119</td>
<td>high freq.</td>
</tr>
<tr>
<td>Ib</td>
<td>4</td>
<td>low freq.</td>
</tr>
<tr>
<td>IBM</td>
<td>9</td>
<td>low freq.</td>
</tr>
<tr>
<td>i.e.</td>
<td>97</td>
<td>high freq.</td>
</tr>
<tr>
<td>NASA</td>
<td>680</td>
<td>high freq.</td>
</tr>
<tr>
<td>MA</td>
<td>2</td>
<td>low freq.</td>
</tr>
<tr>
<td>Mp</td>
<td>1</td>
<td>low freq.</td>
</tr>
<tr>
<td>PC</td>
<td>70</td>
<td>high freq.</td>
</tr>
<tr>
<td>PM</td>
<td>1</td>
<td>low freq.</td>
</tr>
<tr>
<td>ph</td>
<td>11</td>
<td>mid freq.</td>
</tr>
<tr>
<td>PLC</td>
<td>2</td>
<td>low freq.</td>
</tr>
<tr>
<td>VAT</td>
<td>1</td>
<td>low freq.</td>
</tr>
<tr>
<td>UNESCO</td>
<td>7</td>
<td>low freq.</td>
</tr>
<tr>
<td>UK</td>
<td>49</td>
<td>high freq.</td>
</tr>
<tr>
<td>USA</td>
<td>924</td>
<td>high freq.</td>
</tr>
</tbody>
</table>
Function words

Lexical words in English are divided into two basic categories: content words and function words. Content words include verbs, nouns, adverbs, and adjectives. Function words, however, are the grammatical categories in English that include prepositions, articles, conjunctions, etc. (Merriam Webster, 2018). Function words have no meaning on their own and perform the grammatical functions of the language. However, some content words such as nevertheless and according to that play the role of function words. Another important feature of function words in making a word list is that it is a closed grammatical category where no new item will be added to it.

The strongest argument in favor of developing a separate list of function words is the idea that function words are qualitatively different from content words (Nation, 2016); the way that a content word is acquired is different from how a function is learned because learning function words is more dependent to acquiring grammatical knowledge (Nation, 2016). A further issue is that function words account for 51% of the token words in BNC showing that they are frequent. In Coxhead’s AWL, there are six function words: albeit, despite, notwithstanding, plus, via, and whereas. However, eight function words are not in most of the English high frequency words: albeit, notwithstanding, whence, and whether. In this study, most function words in K-12 textbooks are placed in the high frequency list. Below is a random sample of such function words.
Table 15. English function words.

<table>
<thead>
<tr>
<th>Word</th>
<th>Freq.</th>
<th>Word list type</th>
</tr>
</thead>
<tbody>
<tr>
<td>above</td>
<td>5859</td>
<td>high freq.</td>
</tr>
<tr>
<td>across</td>
<td>2385</td>
<td>high freq.</td>
</tr>
<tr>
<td>between</td>
<td>13713</td>
<td>high freq.</td>
</tr>
<tr>
<td>can</td>
<td>50510</td>
<td>high freq.</td>
</tr>
<tr>
<td>every</td>
<td>3831</td>
<td>high freq.</td>
</tr>
<tr>
<td>few</td>
<td>3616</td>
<td>high freq.</td>
</tr>
<tr>
<td>however</td>
<td>4650</td>
<td>high freq.</td>
</tr>
<tr>
<td>neither</td>
<td>627</td>
<td>high freq.</td>
</tr>
<tr>
<td>over</td>
<td>2381</td>
<td>high freq.</td>
</tr>
<tr>
<td>though</td>
<td>1708</td>
<td>high freq.</td>
</tr>
<tr>
<td>upon</td>
<td>1079</td>
<td>high freq.</td>
</tr>
<tr>
<td>unless</td>
<td>363</td>
<td>high freq.</td>
</tr>
<tr>
<td>via</td>
<td>120</td>
<td>high freq.</td>
</tr>
<tr>
<td>what</td>
<td>47797</td>
<td>high freq.</td>
</tr>
</tbody>
</table>
Developing and validation of word lists

The line of research on word lists has applied two major validation methods. Coxhead (2000), Coxhead and Hirsh (2007), Nation (2006), and Gardner and Davies (2013) are principal studies using text coverage as the validation method. The other method, however, used psychological reaction behavior to validate a word list (Gries, 2010; New, Brysbaert, Veronis, & Pallier, 2007). Beyond frequency in this second method, reaction time is affected by a number of factors like eye movement ability, letter decoding speed, and semantic complexity, to name a few. As a result, the latter method doesn’t fit the requirements of a corpus-driven approach in making a word list. Therefore, I used the text coverage type (see chapter 2 for a definition and literature review) as the validation method for the present dissertation study. In doing so, I used AntWordProfiler software (Anthony, 2014) to examine the text coverage provided by the word lists of this study.

AntWordProfiler software

AntWordProfiler is a software developed by Anthony (2014) to analyze corpus data on lexical profiling. The software has two main tools. The first one that appears in the middle of the window of the software is a tool for developing general vocabulary profiling. I used this tool to run the analysis in this section of the dissertation. Through this tool, I generated word lists statistics and frequency information about the five word lists of this study. This tool also uses the results of the research of Nation to compare the text coverage of a word list against a group of level lists that can be based on either word family or lemma. I also used vocabulary profile tool, the second main tool of the software, to load
baseword files into the analysis section of the software. This tool also allows to search the words across a corpus.

**Results**

Research Question #2 entails the following: What are the most commonly used lemmas in U.S.-based K-12 textbooks? Further subquestions incorporate

To what extent are

iv) high-frequency,

v) medium frequency, and

vi) low frequency lemmas,

used in U.S.-based K-12 textbooks?

What are the new academic and STEM-related word lists in U.S.-based K-12 content area textbooks?

This Results section, therefore, presents five word lists—High Frequency, Mid Frequency, Low Frequency, Academic, and STEM-related word lists, which address the research question. It also includes an Essential Word List (EWL). These six word lists include 17,565 lemmas from K-12 textbooks. The High Frequency Word List includes words appearing 100 times or more in the K-12 textbooks corpus. For the Mid Frequency Word List, the range of appearance through K-12 textbooks is between 99 and 10 occurrences. For the Low Frequency Word List, the range of appearance is between 9 occurrences and a single occurrence. The Academic and STEM-related word lists are also divided into two sub-lists of higher and lower frequency words. In High, Mid, Low, and EWL word lists, words are ordered in respect of frequency. In addition, all word lists with
derivational and inflectional forms of lemmas are available at www.myvirs.com/dictionary/.

**High Frequency Word List**

The rationale behind the frequency word lists is based on frequency count (Sinclair, 2005; Nation & Webb, 2011). Words appearing 100 times or more in the whole K-12 corpus are included in the high frequency word list. Coxhead (2000) also picked 100 as the baseline for the text token in her AWL. I decided to take 100 as the border line of high frequency words such that data would not skew toward sight words in my high frequency list. The middle frequency words are words with 10 to 99 tokens in both TUSC and SMACK. All words in low frequency word list have fewer than 10 text tokens.

The High Frequency Word List contains 3,606 lemmas. A complete list with derivational and inflectional forms is available at www.myvirs.com/dictionary. The High Frequency List is shown in Table 16. In the table, the term *freq.* refers to the number of times each lemma appeared in the corpus.
Table 16. The High Frequency List.

<table>
<thead>
<tr>
<th>Freq.</th>
<th>Word</th>
<th>Freq.</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>775747</td>
<td>the</td>
<td>431</td>
<td>eclipse</td>
</tr>
<tr>
<td>378097</td>
<td>be</td>
<td>430</td>
<td>pollinate</td>
</tr>
<tr>
<td>361295</td>
<td>of</td>
<td>429</td>
<td>kinetic</td>
</tr>
<tr>
<td>297511</td>
<td>a</td>
<td>429</td>
<td>prize-giving</td>
</tr>
<tr>
<td>247446</td>
<td>and</td>
<td>428</td>
<td>beside</td>
</tr>
<tr>
<td>243373</td>
<td>to</td>
<td>428</td>
<td>excite</td>
</tr>
<tr>
<td>185046</td>
<td>in</td>
<td>428</td>
<td>fresh</td>
</tr>
<tr>
<td>118803</td>
<td>way</td>
<td>428</td>
<td>gain</td>
</tr>
<tr>
<td>107940</td>
<td>you</td>
<td>427</td>
<td>border</td>
</tr>
<tr>
<td>105481</td>
<td>that</td>
<td>427</td>
<td>pizza</td>
</tr>
<tr>
<td>73894</td>
<td>have</td>
<td>426</td>
<td>geography</td>
</tr>
<tr>
<td>63724</td>
<td>this</td>
<td>425</td>
<td>huge</td>
</tr>
<tr>
<td>63014</td>
<td>use</td>
<td>423</td>
<td>beat</td>
</tr>
<tr>
<td>62504</td>
<td>they</td>
<td>423</td>
<td>modeled</td>
</tr>
<tr>
<td>61359</td>
<td>or</td>
<td>423</td>
<td>recycle</td>
</tr>
<tr>
<td>59402</td>
<td>we</td>
<td>423</td>
<td>American</td>
</tr>
<tr>
<td>56463</td>
<td>by</td>
<td>422</td>
<td>definite</td>
</tr>
<tr>
<td>55294</td>
<td>as</td>
<td>421</td>
<td>astronomy</td>
</tr>
<tr>
<td>55130</td>
<td>on</td>
<td>421</td>
<td>expose</td>
</tr>
<tr>
<td>50510</td>
<td>can</td>
<td>421</td>
<td>quartile</td>
</tr>
<tr>
<td>49647</td>
<td>with</td>
<td>420</td>
<td>everyday</td>
</tr>
<tr>
<td>47797</td>
<td>what</td>
<td>420</td>
<td>haploid</td>
</tr>
<tr>
<td>45749</td>
<td>from</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
nobody 404
time 403
water 403
value 403
form 403
line 403
figure 402
than 402
cell 401
would 401
function 401
answer 400
but 399
may 399
solve 398
energy 398
also 398
into 398
first 398
graph 397
see 397
like 396
problem 395
it 394
out 394
below 393
some 392

title 404
breathing-space 403
immediacy 403
justice 403
succession 403
whenever 403
cry 402
lipid 402
bread-winner 401
stream-water 401
non-document 400
soldier 400
thermal 399
voluntary 399
corn 398
expanse 398
football 398
pet 398
route 398
medical 397
micro-instruction 397
butterfly 396
commute 395
cream 394
motor-vehicle 394
hydrocarbon 393
deposit 392
<table>
<thead>
<tr>
<th>Term</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>up</td>
<td>14414</td>
</tr>
<tr>
<td>give</td>
<td>14344</td>
</tr>
<tr>
<td>follow</td>
<td>13714</td>
</tr>
<tr>
<td>between</td>
<td>13713</td>
</tr>
<tr>
<td>angle</td>
<td>13626</td>
</tr>
<tr>
<td>same</td>
<td>13444</td>
</tr>
<tr>
<td>area</td>
<td>13311</td>
</tr>
<tr>
<td>need</td>
<td>12884</td>
</tr>
<tr>
<td>people</td>
<td>12829</td>
</tr>
<tr>
<td>work</td>
<td>12772</td>
</tr>
<tr>
<td>numbers</td>
<td>12660</td>
</tr>
<tr>
<td>state</td>
<td>12377</td>
</tr>
<tr>
<td>table</td>
<td>12258</td>
</tr>
<tr>
<td>take</td>
<td>11751</td>
</tr>
<tr>
<td>system</td>
<td>11737</td>
</tr>
<tr>
<td>get</td>
<td>11557</td>
</tr>
<tr>
<td>change</td>
<td>11538</td>
</tr>
<tr>
<td>add</td>
<td>11347</td>
</tr>
<tr>
<td>look</td>
<td>11186</td>
</tr>
<tr>
<td>plant</td>
<td>11183</td>
</tr>
<tr>
<td>because</td>
<td>11122</td>
</tr>
<tr>
<td>help</td>
<td>11020</td>
</tr>
<tr>
<td>year</td>
<td>10970</td>
</tr>
<tr>
<td>most</td>
<td>10913</td>
</tr>
<tr>
<td>left</td>
<td>10829</td>
</tr>
<tr>
<td>quarter</td>
<td>10778</td>
</tr>
<tr>
<td>both</td>
<td>10609</td>
</tr>
<tr>
<td>induction</td>
<td>392</td>
</tr>
<tr>
<td>magma</td>
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480 neuron 105 arctic
480 rare 105 biosphere
480 re-capture 105 cement
480 taste 105 daylight
480 t-shirt 105 deficit
479 institute 105 emphasis
479 sale-room 105 germinate
479 stretch 105 harbor
478 co-act 105 impress
        interpretation-computation
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476 hide 105 monomial
476 journal 105 operon
476 overlap 105 roller-coaster
        sub-sub-committee
broad-bean

elevate

kidney

dust

geno...
encourage
float
kilogram
underline
painting
enjoy
rank
horse
mitochondria
amphibian
street-corner
march
ozone
plain
lunch
none
ovary
phylum
trap
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externality
latitude
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sediment
null
famous
fascinate
grace
grocery
larval
leak
rock-drill
slit
arch
architecture
chase
cloud
consult
glove
breed
halogen
insurance
obese
oval
recursion
short-list
somehow
spade
squeak
summation
rail
volt
**Mid Frequency Word List**

The Mid Frequency Word List has 5,006 lemmas ordered in respect of frequency. The list represents lemmas that appeared between 99 and 10 times within the corpus. For a complete list of mid-frequent words with derivational and inflectional forms, check [www.myvirs.com/dictionary](http://www.myvirs.com/dictionary).

Table 17. Mid Frequency Word List.

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bitter         intimacy
disprove       intolerance
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electronegativity ivy
ford           keystone
inventory      knight
knee-trembler  locust
lawn-mower     m
neat           mantis
nebula         meantime
nectar          micronutrient
pre-conference milkweed
residual       neon-sign
score-draw     ovum
squirrel      peel
steroid        perch
straightforward phlogiston
stratification picture-gallery
unite          pipeline
vegetate       plank
vs             pox
widespread     preposition
anemia         presently
barely         provoke
cardinal  pseudopod
confess  purse-string
dissociate  quit
equinox  re-box
heal  regroup
inorganic  roam
kit-bag  roger
mad-house  scold
menstruate  scorn
mini-league  sea-monster
node  sextant
persist  shelf-grip
pest  shellfish
purchase  shuffle
servant  singer-songwriter
subset  sleeping-pill
thermostat  steel-casting
trillion  synthase
cellular  tomb
cascade  tonsil
cucumber  tryptophan
drug  univariate
embryonic  venom
guanine  victor
latter  vivid
longitudinal  von
murder  winged
nominate
qualify
stair-well
sundial
bank
brittle
buoyant
dermis
dodder
cabinet
homozygote
inject
intermolecular
intrude
invasion
maple
metaphase
pharynx
polypeptide
pretend
propel
sea-port
shortage
therapy
toe
complexion
cure

writ
anaconda
antecedent
brood
bugle
burst
calcite
campground
casual
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command
contractor
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curb
deploy
dial
duce
dumbbell
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flare
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impair
elder
erase
exhale
jurisdiction
moth
parking-token
prairie
implement
reinforce
spam
stigma
thymine
wipe
administer
bang
crash
dart
electrochemistry
excerpt
frank
glad
granite
mall
nonfiction
nonmetals
peaceful
petition
impermeable
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indigestible
iodide
jane
ladybugs
ligand
linguistic
louis
madness
map
metaphor
microscopy
nonviolent
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lichen  
proto-oncogene  
sex  
tentacle  
terrify  
tonight  
underwater  
vital  
astrolabe  
brave  
circle  
dean  
dull  
gorilla  
handle  
horn  
hot  
lancelet  
markup  
participation  
pearl  
pro-catholic  
sketch  
sound-pulse  
ranch  
rap  
recombination  
relocate  
reprint  
restate  
restrain  
safeguard  
saltwater  
self-revelation  
semi-luxury  
slab  
snowball  
spatially  
stance  
staple  
startle  
stein  
stink  
suction  
supersaturated  
sur  
tar  
transgress  
vacancy  
viscous  
wart
spit
super-glue
ambiguity
barrel-organ
bump
carpet-bagger
coupon
flat
late
loaf
package
parent
phagocyte
rot
summer
boycott;breakdown
cash-register
crisis
delicate
exhibit
merchant
obligation
paddle
starfish
stratosphere
subphylum
accessory
anemometer
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arthritis
bailey
beaver
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board
boxing-match
breakwater
buddy
chill
clack
combat
comp
conquest
counteract
cumbersome
dance
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decode
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detergent
diff
divorce
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estrogen 83
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huff 83
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joseph 83
leap 83
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sixteenth 83
taxi 83
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duplicate 82
extraneous 82
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exon 23
eye 23
fireplace 23
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foul 23
gault 23
glance 23
gunpowder 23
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herbaceous 23
high-flyer 23
hydride 23
intricate 23
jug 23
lane-end 23
lengthen 23
lethal 23
leucoplast 23
levy 23
lumen 23
measles 23
merge 23
midrange 23
mid-seventeenth-century
pin
prison-ship
sculpt
sense-perception
stock
van
anti-inflammatory
arid
ballot
blueberry
cheap-thrill
concurrent
convict
deliberate
dialogue
eager
fetal
impeach
incentive
motor
musician
navigate
ovulate
retail
suffix
assort

23 mono-poly
23 mop
23 non-eligible
23 nonnegative
23 nucleolus
23 nucleon
23 nursing-home
23 od
23 orthocenter
23 osteoclast
23 pail
23 pandemic
23 pants
23 parrot
23 pheromone
23 phoenix
23 photographed
23 purine
23 quarrel
23 raft
23 re
23 re-capitalize
23 recombine
23 rhizoid
23 ripen
23 rook
23 sapiens
fallopian  wildflower
  gal        yell
grasshopper zooplankton
id           adjourn
knees-up     aerospace
lattice      agenda
monoxide     agonize
offshore     alchemy
platelet     apartheid
polyhedron   apical
prisoner-of-war atop
prominence   autocracy
rebel        backup
romance      barbecue
sixteen-year-old barter
skip         baryon
spot         boat
step-sibling buoy
taproot      celery
tray         cervical
versa        chimney
coronal      cocaine
disrupt      confer
dent         crank
disrupt      desktop
disrupt      dissect
disrupt      dopamine
pigeon  
professor  
repulsion  
scape  
secretion  
skull  
sour  
stalk  
stir  
sympathy  
terror  
thyroid  
titrate  
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tony  
top-seller  
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beverage  
capsize  
cheer  
contest  
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prevail
session
ticket-collector
tumble-dryer
annoy
anybody
apartment
bathroom
bless
bracelet
dicot
dissipate
doubt
drip
eject
elongate
execute
exit
innate
mosquito
over-charge
prose-writing
resign
ring
sea-boot
shoulder
chilly
cobalt
corpse
crusade
cumulonimbus
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disintegrate
disregard
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endospore
entomology
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fingertip
flock
fluff
footage
forestry
garden
gasp

gloss
grandchildren
grove
grumble
hallway
hatchling
hydrothermal
submarine
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sulfate

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oscula
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plummet
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felony  reshape  12
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heptagon  rho  12
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osteoporosis  self-deception  12
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peninsula  sill  12
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remnant
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synovial
thrill
timber
tinker
toothpaste
triphosphate
unprecedented
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yogurt
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goat-antelope
goo
gospel
grill
headquarter
healthcare
hematite
high-brow
hiss
hoe
hostage
hover
hydra
icosahedron
impost
impoverish
inconsistency
infraclass
jpeg
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kin
knit
laxative
ledge
leftmost
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alkaline
amber
apothem
blister
brute
cochlea
confound
couch
den
differentiate
dosage
doughnut
farmland
fatigue
fiery
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hookworm
horseshoe
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innocence
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intracellular
krill
laughter-line
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macronutrients

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litigant
lux
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| 31 | scarlet          | 11 | peasant-proletarian |
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| 31 | skeptical        | 11 | ponder          |
| 31 | skydive          | 11 | pool-liner      |
| 31 | slug-pellet      | 11 | pounce          |
| 31 | snack-bar        | 11 | precinct        |
|     |                  |    | propagate       |
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regrow
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| 30 | spy-hole          | 10 | articulate      |
| 30 | squash            | 10 | ascertain       |
| 30 | stratus           | 10 | balboa          |
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| 30 | thou              | 10 | bat             |
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| 29 | anabolic          | 10 | benzoate        |
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| 29 | bamboo           | 10 | bizarre         |
| 29 | bodily           | 10 | blunt           |
| 29 | brine            | 10 | bod             |
| 29 | burial           | 10 | booby-trap      |
| 29 | chipmunk         | 10 | brisk           |
| 29 | circadian        | 10 | bust            |
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| 29 | encompass        | 10 | chug            |
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| 29 | fragile          | 10 | cop             |
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| 29 | hoof             | 10 | daydream        |
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pone
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posterity
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prehistoric
primula
problematic
profess
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subfamily  quilter
tern  raspberry
tic  reabsorption
cyclist  re-bore	
tug  recalculate
tumble  recycler
librarian  redshift
uptake  ref
vane  re-format
vigor  regent
warrant  rendition
anal  replica
antacid  revival
antique  rick
appellate  rill
banquet  rite
barber-surgeon  roadside
broom  salicylic
champagne  salt-cellar
cinnamon  scavenge
crinoid  scrabble
demon  seabird
desalinate  sea-green
disgust  seahorse
doorway  seashell
endeavor  seduce
27 enlighten 10 self-citation
27 esteem 10 sesame
27 expertise 10 sidekick
27 flee 10 sidereal
27 fond 10 single
27 gang-boss 10 skipping-robe
27 glycerol 10 slogan
27 gnu 10 sludge
27 goldfish 10 smear
27 herd 10 snapdragon
27 hive 10 snowshoe
27 hoover 10 socioeconomic
27 hug 10 sorrow
27 hypertonic 10 spaceflight
27 indistinguishable 10 spar
27 innermost 10 spirogyra
27 instability 10 spook
27 intraspecific 10 spouse
27 ism 10 squad
27 iteration 10 staghorn
27 kneel 10 stalagmite
27 lettuce 10 stealth
27 lightweight 10 stegosaurus
27 lollipop 10 stereotype
27 luteum 10 stitch
27 luteum 10 strangeness
27 maglev 10 strap
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microevolution
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patriot
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Low Frequency Word List

The Low Frequency Word List, shown in Table 18, has 8,080 lemmas. Words in this list had between nine occurrences and a single occurrences in the corpus. For a complete list of low-frequent words with all derivational and inflectional forms, check www.myvirs.com/dictionary.

Table 18. Low Frequency Word List.

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buttercup  nineties
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caiman  nine-to-fiver
calligraphy  niobium
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<td>subsonic</td>
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<td>substantia</td>
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<td>subtend</td>
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3 trichinosis
3 trifle
3 trilogy
3 triode
3 trioxide
3 trisphosphate
3 trombone
3 tsar
3 tuition
3 turpentine
3 tympanum
3 typhoid
3 typography
3 uncontrollable
3 underscore
3 underway
3 underwood
3 unwieldy
3 upholstery
3 upland
3 usher
3 vantage
3 vat
3 velocipede
3 velum
3 vent
3 ventriloquist
1 subtlety
1 subvention
1 suchlike
1 suit
1 suitor
1 sumac
1 sunbelt
1 sunbird
1 sunder
1 sunroof
1 sunup
1 superbug
1 supercapacitor
1 supercell
1 superclass
1 supercool
1 superdeep
1 ego
1 superjumbo
1 supernatant
1 supersaturation
1 supersonic
1 supinate
1 surly
1 surmise
1 surreptitiously
1 suture
3 venue
3 verbatim
3 veronica
3 vert
3 viceroy
3 vid
3 villain
3 vindicate
3 vintage
3 viridian
3 visa
3 vise
3 vocation
3 volley
3 vulcanization
3 wade
3 waistband
3 wan
3 wat
3 waterwheel
3 weakling
3 weal
3 weatherman
3 whack
3 whim
3 whine
3 whipworm
1 suzerainty
1 swab
1 swallowtail
1 swami
1 swatch
1 swath
1 swath
1 sweepstake
1 swindler
1 switchman
1 swordsman
1 syllabus
1 syncopated
1 syndicate
1 tacky
1 tactile
1 tai
1 tailfin
1 taillights
1 tallow
1 tam
1 tambura
1 tammy
1 tamp
1 tamper
1 tantalize
1 tantrum
1 tapa
| 2 | accolade                      | 1 | thistle                             |
| 2 | accordion                     | 1 | thither                             |
| 2 | accursed                      | 1 | thong                               |
| 2 | acetaminophen                 | 1 | thong                               |
| 2 | acetoacetic                   | 1 | thorp                               |
| 2 | acrid                         | 1 | threefold                           |
| 2 | acrostic                      | 1 | thrift                              |
| 2 | actinium                      | 1 | thromboplatin                       |
| 2 | admonish                      | 1 | thrombosis                          |
| 2 | adrenocorticotropic           | 1 | thwart                              |
| 2 | advection                     | 1 | thyroxin                            |
| 2 | aeruginosa                    | 1 | thyself                             |
| 2 | aforesaid                     | 1 | tier                                |
| 2 | aft                           | 1 | tiff                                |
| 2 | agaric                        | 1 | tiller                              |
| 2 | agronomic                     | 1 | timberland                          |
| 2 | airfield                      | 1 | timeliness                          |
| 2 | airmail                       | 1 | tine                               |
| 2 | airspace                      | 1 | tined                               |
| 2 | airspeed                      | 1 | tingly                              |
| 2 | airwaves                      | 1 | tinkle                              |
| 2 | akin                          | 1 | tipis                               |
| 2 | albatross                     | 1 | tithe                               |
| 2 | albumin                       | 1 | titian                              |
| 2 | aliphatic                     | 1 | tocopherol                          |
| 2 | allegation                    | 1 | tog                                 |
| 2 | allosteric                    | 1 | toggle                              |
| 2 | admission                     | 1 | toile                               |
2 alphonso
2 amoxicillin
2 amphitheater
2 anarchy
2 android
2 anew
2 angiogenesis
2 antibaryons
2 anticonvulsant
2 antimalarial
2 antiporter
2 anyplace
2 apache
2 apheric
2 aplasia
2 apocryphal
2 apostle
2 apperception
2 appraise
2 aptitude
2 aquamarine
2 archaeabacterial
2 archbishop
2 archery
2 areal
2 areole
2 argentum
1 tonto
1 topo
1 toro
1 tori
1 torpedo
1 tort
1 totipotent
1 tourniquet
1 towboats
1 towhees
1 trabecular
1 transglutaminase
1 transhumance
1 transliterate
1 trashcan
1 travers
1 treble
1 tree-creeper
1 treetop
1 trespass
1 triangulate
1 tribespeople
1 tricarboxylic
1 trichloroethylene
1 triclinic
1 tricolored
1 triiodothyronine
1 trike
2 aria
2 arteriosclerosis
2 artichoke
2 articulation
2 ascariasis
2 astrocyte
2 astute
2 atlatl
2 atman
2 atoll
2 atrocity
2 attest
2 audit
2 audition
2 auld
2 auspices
2 autocrat
2 autocratic
2 autoinfection
2 autopsy
2 avow
2 awash
2 azalea
2 baccalaureate
2 backcountry
2 backfire
2 backflow
1 tringle
1 trinitrotoluene
1 trinket
1 trinucleotide
1 triplex
1 triplicate
1 triploblastic
1 tripod
1 triticale
1 trivet
1 trochee
1 troubleshoot
1 trouble-shooter
1 truce
1 trump
1 tuberosity
1 tumbleweeds
1 tunic
1 turbidity
1 turbo-alternator
1 turbofan
1 turducken
1 tut
1 twain
1 tweet
1 twill
1 twine
| 2  | backseat           | 1  | unbridled        |
|    | backside           | 1  | underdog         |
|    | backstage          | 1  | undergrad        |
|    | bacteriorhodopsin  | 1  | underprivileged  |
|    | bailor             | 1  | underwear        |
|    | baleful            | 1  | undying          |
|    | balk               | 1  | unheralded       |
|    | ballerina          | 1  | unicorn          |
|    | ballistic          | 1  | unilateral       |
|    | balsam             | 1  | unis             |
|    | bandana            | 1  | unkempt          |
|    | bane               | 1  | unpalatable      |
|    | bantam             | 1  | unpasteurized    |
|    | banzai             | 1  | unperturbed      |
|    | barbershop         | 1  | unruly           |
|    | barleycorn         | 1  | unstrung         |
|    | barney             | 1  | unsung           |
|    | baroque            | 1  | upbraid          |
|    | barrio             | 1  | upbring          |
|    | **baseboard**      | 1  | upkeep           |
|    | basketful          | 1  | upperclassmen    |
|    | bastille           | 1  | upriver          |
|    | bathyal            | 1  | uproar           |
|    | bawdy              | 1  | upscale          |
|    | bazaar             | 1  | upturn           |
|    | beadle             | 1  | urate            |
|    | beany              | 1  | uric             |
2 biuret 1 vita
2 blackhead 1 vitriol
2 blackish 1 vodka
2 blaspheme 1 voluminous
2 blasphemy 1 wallow
2 blithe 1 wand
2 bloodedness 1 warden
2 bloodhound 1 warlike
2 bloodletting 1 warp
2 bloodthirsty 1 wash
2 blotch 1 wassail
2 blowdown 1 watchman
2 blowhole 1 watercolor
2 blowout 1 watercourse
2 bluestone 1 waterfront
2 bluffs 1 waterhole
2 boardinghouse 1 waterpower
2 boardwalk 1 weathercock
2 bobsled 1 webmaster
2 bobtail 1 weevil
2 bodybuilder 1 wellhead
2 bog 1 wend
2 boggle 1 wharf
2 bolus 1 whimsical
2 bona 1 whippersnapper
2 bondholder 1 whirlwind
2 bong 1 whirr
| 2 bongo                  | 1 whitefly             |
| 2 bonk                   | 1 whiteout             |
| 2 boob                    | 1 whitetip             |
| 2 bookkeeping            | 1 whizzbang            |
| 2 bookseller             | 1 whoa                 |
| 2 bookshelves            | 1 whomever             |
| 2 borer                  | 1 wiener               |
| 2 bosom                  | 1 wigwam               |
| 2 bourgeois              | 1 wildland             |
| 2 bourgeoisie            | 1 wile                 |
| 2 bouzouki               | 1 wily                 |
| 2 boxy                   | 1 wince                |
| 2 brahma                 | 1 windfall             |
| 2 brainer                | 1 windowpane           |
| 2 brat                   | 1 windscreen-wiper     |
| 2 brawn                  | 1 windshield           |
| 2 bray                   | 1 windsurfer           |
| 2 breadbasket            | 1 windup               |
| 2 breastbone             | 1 wireframe            |
| 2 brickyard              | 1 wishbone             |
| 2 bridge                 | 1 wizard               |
| 2 brig                   | 1 woo                  |
| 2 brindle                | 1 woodcut              |
| 2 brio                   | 1 woodwind             |
| 2 bristlecone            | 1 wordplay             |
| 2 bristletails           | 1 workbench            |
| 2 bronzy                 | 1 workhorse            |

400
<p>| 2   | broomrape          | 1   | workmanship                      |
| 2   | bubo              | 1   | workshare                        |
| 2   | bucker            | 1   | worktop                          |
| 2   | bulbourethral     | 1   | workweek                         |
| 2   | bunkhouse         | 1   | world-beater                      |
| 2   | burgeoning        | 1   | wreath                           |
| 2   | burgundy          | 1   | wrench                           |
| 2   | bursa             | 1   | wristwatch                        |
| 2   | businesspeople    | 1   | writhe                           |
| 2   | butadiene         | 1   | xenon                            |
| 2   | buttermilk        | 1   | xylophone                         |
| 2   | bygone            | 1   | xylose                           |
| 2   | byway             | 1   | yak                              |
| 2   | cacao             | 1   | yawn                             |
| 2   | cackle            | 1   | yean                             |
| 2   | caeca             | 1   | yearn                            |
| 2   | caecum            | 1   | yellowhammer                      |
| 2   | calabash          | 1   | yew                              |
| 2   | calcified         | 1   | yip                              |
| 2   | calicle           | 1   | yon                              |
| 2   | californium       | 1   | yonder                           |
| 2   | callas            | 1   | yuck                             |
| 2   | callosum          | 1   | yurt                             |
| 2   | callus            | 1   | zag                              |
| 2   | candlestick       | 1   | zenial                           |
| 2   | canebrake         | 1   | zeppelin                         |
| 2   | canid             | 1   | zines                            |</p>
<table>
<thead>
<tr>
<th></th>
<th>verb</th>
<th></th>
<th>noun</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>cantaloupe</td>
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<td>zoonosis</td>
</tr>
<tr>
<td>2</td>
<td>capitulate</td>
<td>1</td>
<td>super-ego</td>
</tr>
</tbody>
</table>
K-12 Academic Word List

The Academic Word List, displayed in Table 19, has 461 lemmas and is divided into two sub-lists of higher and lower frequency words. With regard to the developing of academic and STEM-related words, I took a semantic perspective toward word inclusion in the lists (Flowerdew, 2004). In developing the academic list, words that are common among three content areas out of the four (math, science, social studies, and language arts) are included on the list.

Table 19. K-12 Academic Word List.

<table>
<thead>
<tr>
<th>Higher Freq.</th>
<th>Lower Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>area</td>
<td>converse</td>
</tr>
<tr>
<td>chapter</td>
<td>convince</td>
</tr>
<tr>
<td>data</td>
<td>exclude</td>
</tr>
<tr>
<td>factor</td>
<td>exclusive</td>
</tr>
<tr>
<td>vary</td>
<td>finite</td>
</tr>
<tr>
<td>function</td>
<td>infinite</td>
</tr>
<tr>
<td>volume</td>
<td>mutual</td>
</tr>
<tr>
<td>proportion</td>
<td>community</td>
</tr>
<tr>
<td>ratio</td>
<td>register</td>
</tr>
<tr>
<td>coordinate</td>
<td>valid</td>
</tr>
<tr>
<td>evaluate</td>
<td>revolution</td>
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<tr>
<td>formula</td>
<td>credit</td>
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<tr>
<td>formulate</td>
<td>revise</td>
</tr>
<tr>
<td>negate</td>
<td>context</td>
</tr>
<tr>
<td>negative</td>
<td>reside</td>
</tr>
</tbody>
</table>
substitute  contrast
substitution  adjust
label  react
concept  reaction
symbol  hypothesize
symbolic  periodic
predict  cycle
prediction  infer
 correspond  inference
corresponding  evident
involve  adapt
involving  adaption
approximate  evolution
approximation  evolutionary
approximately  globe
core
random  global
randomly  core
convert  projection
conversion  giant
converting  potential
item  dominate
compute  dominant
computation  impact
computer  phase
computing  expose
mode  exposure
section  stable
previous	quotatation

target	traditional

remove	traditional

period	assignment

illustrate	fragment

illustration	imagery

supplement	standardize

supplementary	thesis

annual	version

objective	aspect

spreadsheet
civil

theory
deeption

theoretical

theorize

maximize

maximum

summary

final

job

require

affect

bias

unbiased

tape

radical

technology

capacity
generation
precise
precision
terminate
minimum
focus
reverse
proceed
procedure
commission
research
element
layer
consume
category
portion
code
technique
index
vehicle
consist
site
resource
physical
partner
energy
initial

insight
integral
integrity
deduce
decline
crucial
allocate
analogy
arbitrary
assemble
bond
brief
bulk
capable
fluctuate
hierarchy
debate
compile
compensate
deviate
diminish
offset
ongoing
invoke
paradigm
subsidy
revenue
isolate
specific
journal
visualize
overlap
normal
complex
task
demonstrate
medium
equip
identical
alter
alternate
voluntary
volunteer
transport
transportation
conduct
assign
obtain
fund
fundamental
maintain
documentary
restrict
temporary
enhance
ethic
ethnic
exceed
explicit
implicit
exploit
exploitation
extract
facilitate
devote
federal
ministry
prospect
protocol
pursue
orient
restore
restrain
practitioner
pose
nuclear
inhibit
inhibition
denote
K-12 STEM-related Word Lists

The STEM-related word lists, shown in Tables 20 and 21, are composed of two sub-lists of Math (184 lemmas) and Science (228 lemmas). With respect to the STEM-related list, words that are domain specific are included on the list; in other words, all words appearing only in one content area (math or science) but not in others are included in the STEM-related word list. In addition, each sub-list is divided into two sections of higher and lower frequency words.

Table 20. K-12 STEM-related words: Math.

<table>
<thead>
<tr>
<th>Higher Freq.</th>
<th>Lower Freq.</th>
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<tbody>
<tr>
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<tr>
<td>equation</td>
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<td>graph</td>
<td>lateral</td>
</tr>
<tr>
<td>graphic</td>
<td>tank</td>
</tr>
<tr>
<td>fraction</td>
<td>associative</td>
</tr>
<tr>
<td>fractional</td>
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<td>triangle</td>
<td>assessment</td>
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<tr>
<td>triangular</td>
<td>adjacent</td>
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<tr>
<td>percent</td>
<td>finite</td>
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<td>infinite</td>
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<td>infinitely</td>
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<td>factorization</td>
<td>diagram</td>
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<td>math</td>
<td>altitude</td>
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<tr>
<td>mathematical</td>
<td>angle</td>
</tr>
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<td>mathematician</td>
<td>arc</td>
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<tr>
<td>meter</td>
<td>arithmetic sequence</td>
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quadratic
determinant
rotate
diagonal
rotation
dilation
rotational
dime
direct variation
discriminant
discriminant
dividend
dodecahedron
trapezoid
ellipse
reciprocal
equals
quadrilateral
event
perpendicular
factorial
sketch
figure
diagram
discount
frequency
trigonometric
gird
histogram
acute
inequality
obtuse
matrix
distance
parenthesis
mode
hypotenuse
monomial
commutative
scatterplot
Table 21. K-12 STEM-related words: Science.

<table>
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</thead>
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<td>balloon</td>
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<td>organism</td>
<td>sperm</td>
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<td>atom</td>
<td>beaker</td>
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<tr>
<td>atomic</td>
<td>equator</td>
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<tr>
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<td>mercury</td>
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<td>beach</td>
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<td>respire</td>
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<tr>
<td>atmosphere</td>
<td>respiration</td>
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<td>planet</td>
<td>organic</td>
</tr>
<tr>
<td>environment</td>
<td>polar</td>
</tr>
<tr>
<td>environmental</td>
<td>hemisphere</td>
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<tr>
<td>fossil</td>
<td>reptile</td>
</tr>
<tr>
<td>dense</td>
<td>radioactive</td>
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<tr>
<td>density</td>
<td>groundwater</td>
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<td>helium</td>
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<td>acid</td>
<td>spectrum</td>
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<tr>
<td>acidic</td>
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gene
genetic
gravity
gravitational
continent
continental
tissue
muscle
erode
erosion
physical
climate
ecosystem
bacterium
bacteria
trait
hydrogen
ion
ionic
chromosome
dioxide
nucleus
fuel
laboratory
lab
fluid
radiate
radiation
contour
metamorphic
vascular
lever
rocket
era
ozone
buoy
buoyant
hurricane
elevate
elevation
embryo
jar
mirror
injure
injury
metamorphosis
biotic
abiotic
producer
consumer
herbivore
carnivore
omnivore
scavenger
decomposer
food web
precipitate  Bunsen burner
nutrient     burette
nutrition   funnel
glacier      genetics
orbit        geophysics
glacier      glassware
mammal       graduated cylinder
velocity     herpetology
dissolve     ichthyology
mantle       immunology
absorb       magnetism
photosynthesis mass
fungal       meteorologist
fungi        meteorology
lava         microbiologist
astonomy     microbiology
astronomer   mineral
microscope   mineralogy
vapor        ornithology
vaporize     quantum
neutron      scale
membrane     science
thermal      scientist
humid        seismology
humidity     temperature
igneous      test tube
tropic
tropical theory
nuclear zoology
kinetic experiment
latitude extrapolation

**Essential Word List (EWL) for K-12 ELLs**

The Essential Word List is composed of three sub-lists, presented in Tables 22, 23, and 24: K1 (first 1,000 most frequent words), K2 (second 1,000 most frequent words), and academic words. Each sub-list has two levels of higher and lower frequency words.

Table 22. Essential Word List: K1.

<table>
<thead>
<tr>
<th>Freq.</th>
<th>Word</th>
<th>Freq.</th>
<th>Word</th>
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<td>of</td>
<td>2481</td>
<td>division</td>
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<td>a</td>
<td>2480</td>
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<td>247446</td>
<td>and</td>
<td>2478</td>
<td>degree</td>
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<td>to</td>
<td>2478</td>
<td>rational</td>
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<td>185046</td>
<td>in</td>
<td>2475</td>
<td>carry</td>
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<td>sometime</td>
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<td>require</td>
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<td>2463</td>
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<tr>
<td>63724</td>
<td>this</td>
<td>2462</td>
<td>inside</td>
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</table>
also
to
first
graph
see
like
problem
it
out
below
some
up
give
follow
between
angle
same
area
need
people
work
numbers
state
table
take
system
get
easy
pseudo-operation
friend
enough
exact
characterize
something
west
war
temple-complex
balance
today
over-correct
indicate
lonely-heart
metal
letter
self-interest
variety
sex-role
environment
chromosome
symbol
intercept
out-flow
sense-organ
evolution
change cross
add vote
look decide
plant feel
because life-choice
help build
year motion-picture
most pass
left warm
quarter share
year light-curve
both until
data building
call soil
where station-building
she release
show three-month
explain re-appear
why micro-electric
lesson green
such behave
through self-control
right evidence
move member
new approximate
order drive
image lose
only 2072 big-wig
view 2071 sea-wind
part 2069 magnet
super-power 2067 lifter
no 2065 over-balance
simple 2063 sell
term 2049 am
could 2048 primary
now 2031 hydrogen
word 2029 atmosphere
include 2028 gravity
good 2027 heart
unit 2027 position
open 2018 transport
earth 2008 normal
live 2003 dense
set 2001 super-store
any 1999 ice
self-review 1997 integer
over 1996 fact
read 1991 egg
represent 1990 receive
factor 1985 plate
describe 1978 hear
day 1976 membrane
force 1973 proportion
square 1958 eye
determine 1955 round
two-step 1951 river
place 1950 run
per 1940 chart
group 1940 exist
after 1931 card
direct 1931 flower
know 1929 perform
great 1928 discover
grow 1928 reflect
cause 1927 meaningful
much 1925 quick
chapter 1921 hard
length 1917 vertex
who 1915 source-text
probable 1912 pie-chart
divide 1912 row
high 1908 south-westerly
test 1907 meter
body 1906 never
result 1906 rise
life 1895 suppose
must 1893 plate-layer
equal 1892 self-seed
let 1883 spend
triangle 1876 fossil
side 1875 physical
6836  org  1873  particular
6835  draw  1869  t-short
6785  common  1868  middle
6752  still-large  1865  meet
6735  very  1864  planet
6716  food  1861  believe
6685  another  1857  tissue
6657  learn  1853  weather
6634  world  1851  widen
6618  real  1849  algebra
6540  law  1845  collect
6429  here  1845  house-hold
6413  express  1845  six-year-old
6375  down  1840  bar
6375  multiply  1837  substitute
6370  atom  1828  life-history
6362  small-animal  1823  instead
6308  process  1822  meaning
6249  compare  1822  think
6227  student  1819  lot
6129  object  1818  decrease
6126  importance  1815  translate
6103  long  1810  face
6093  measure  1810  micro-climate
6085  sub-process  1810  micro-fossil
6081  distance  1798  parent
6073  just  1796  count
mile
public
trust-me
land
often
list
type-case
semi-negative
structure
sin
wrist
subject
compound
re-consider
three-inch
box
root
resource
cos
twin-car
material
species
subject-matter
level
rock
sun-worshipper
able

dioxide
turn
pollute
oil-spill
due
mineral
cold-store
construct
nucleus
slave-girl
two-leg
location
tool
safe
rest
dimension
say
cup
replace
efficiency
stem
ever
pdf
score
polar
trade
serve
3941 possible-world coefficient
3936 original perpendicular thousand
3920 always skill
3913 page survey
3910 class talk
3882 distribution removable
3869 keep bear
3831 every dog
3823 without component
3815 study contrast
3801 co-worker display
3798 red earthquake
3783 charge ago
3780 those accord
3777 choose ray
3770 human-being return
3739 ocean deep
3706 thought-experiment outline
3702 close resist
3690 early asymptote
3685 positive virus
3683 half thus
3668 property-owner socialism
3660 under succeed
3659 analyze fit
3656 develop recall
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<th>Word</th>
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false
totem-pole
fair
suggest
re-combine
reproduction
storage
sub-project
pseudo-device
re-examine
lung
whose
swimming-pool
straight-jacket
chance
semi-regular
sky
cool
non-decision
fruit
business
sine
trigonometry
rain-forest
communicate
hi
respect
drug
push-up
vascular
media
parameter
step-sister
intense
mitosis
portion
smart-drug
investigate
stick
felt
regard
sixth-former
space-arc
beyond
reciprocal
paint
passage
slow
brother
arrow
conduct
wrong
balloon
melt
velocity
re-fuel
exercise
fast
site
benefit
gold
earn
winter
someone
universe
save
cosine
message
habitat	
twice
snow-bank
binominal
interact
principle
trial
fertility	
tend
eventuality
go-fast
carbohydrate
flight
listen
agriculture
stomach
violate
fear
grid
compose
rich
cook
street-woman
para-military
band
attempt
plastic
sea-grass
simulate
effort
ended
inner
rope
hunt
mentally
oxidation
realize
wild
advantage
counter-argument
rough
especial
enzyme
bad
theme
arm
glucose
revolt
future
quadrilateral
invert
window
rose-garden
partner
heavy
behind
trouble-spot
edge
seven-year-old
instance
risk
accept
customer
dimensional
touch
aspect
surprise
colonial
non-customer
transcribe
parasite
staging-post
cytoplasm
pump-prime
wrap
neutron
glacier
crime
persuade
pollen
address
carrying-on
medium
purple
reverse-punch
chloroplast
street-fight
convention
neuron
rare
re-capture
taste
empire
slave
pathogen
boundaries
erode
tying
input-output
trip
internal
polka-dot
race
signal
hill
fish-farm
freeze
sand-hill
coin-op
gallon
subtraction
shadow
infinite
power
station
battery
conserve
education
t-shirt
institute
sale-room
stretch
co-act
gather
hide
journal
overlap
sub-sub-committee
plasma
infect
condition
forward
presence
snake
labor
pain
principal
consider
worm
hyperbola
reject
occupy
upward
coin
ready

anything

red-brown

strike

ax

output

option

sea-flat

g eo log y

season

gland

numeric

else

distinct

kingdom

minute-book

paragraph

classification

ion-exchange

midpoint

southern

re-arrange

renewable

thick

election

ovary

phylum

trap

replicate

externality

latitude

brief

sediment

null

famous

eclipse

pollinate

kinetic

prize-giving

beside

excite

fresh

gain

tens

border

pizza

geography

huge

beat

modeled

recycle

american

451
god  definite
meiosis  astronomy
supplement  expose
colonize  quartile
ticket  everyday
eliminate  haploid
familiar  preimage
defend  aquatic
guess  catch
official  puberty
mole  re-assign
marble  coffee
sea-coast  fall
sketch-pad  night-club
union  sub-sector
dilate  diamond
mouth  diet
fuel  amplitude
ger-gain  decline
cm  desire
board  please
nation  shore
over-control  smile
physician  tropics
consume  archaea
self  soft
erupt  mercury
efficient, friction, non-consumer, push, screen, strength, puppet, overall, whisker, lay, tenant-farmer, gamete, bounded, everyone, flip, hope, rapid, speaker, thunder-storm, partial, quotient, buy, representation, toilet-roll, copyright, permutation, mega-deal, butterfly, commute, cream, motor-vehicle, hydrocarbon, deposit, induction, magma, mantle, network, push-bike, teacher-researcher, semi-conductor, wet, sir, chordate, grain, migration, photo-cd, tidal, secure, argue, non-executive, exterior, toxin, fence, slide
667 belong
666 fold
666 microscope
666 progress
666 speech
666 upper
662 inherit
661 pre-adaptation
661 substitution
660 prefer
659 quite
656 bottle
655 milk-yield
654 checkpoint
653 weak
652 honey-guide
649 nothing
648 fail
648 slight
648 vehicle
646 offspring
646 purchase
646 toffee-apple
646 toss
645 exchange
645 investigation
645 perhaps
383 immigrant
383 repair
383 steel-worker
382 debate
382 drink
382 fund
382 perspective
382 swim
381 museum
380 sensor
380 terminal
380 wavelength
379 alter
379 sec
379 stock-take
378 conic
378 decade
378 mar
378 nest
378 ounce
378 stone-thrower
377 confuse
377 elephant
377 gray
377 strand
376 propose
376 vitamin
| 643 | background | 375 | deck |
| 643 | compute | 375 | thank |
| 643 | stand-alone | 374 | alcohol |
| 642 | environ | 374 | pie |
| 642 | yield | 374 | postulate |
| 641 | profit | 373 | beneath |
| 640 | onto | 373 | loose-liver |
| 636 | diffuse | 373 | workbook |
| 635 | procedural | 372 | enclose |
| 635 | self-interaction | 372 | photo-copy |
| 634 | eating-disorder | 372 | poison |
| 634 | regression | 372 | re-mark |
| 634 | wheel | 372 | review |
| 632 | sit | 371 | authority |
| 632 | wonder | 371 | comprehend |
| 631 | concern | 371 | lab |
| 630 | moment | 371 | load |
| 629 | experiment | 371 | mistake |
| 629 | possibility | 370 | split |
| 628 | precise | 369 | capability |
| 627 | animate | 369 | solubility |
| 627 | equilibrate | 369 | whatever |
| 627 | neither | 368 | target |
| 627 | trapezoid | 367 | ensure |
| 626 | news-stand | 367 | prize |
| 626 | predator | 366 | alike |
| 624 | galaxy | 366 | anyone |
orange, dinosaur, disagree, multicellular, allergen, secrete, configure, giant, skeletal, unless, calcium, sight, bicycle, govern, para-legal, commerce, flood, narrow, fun, mention, sit-up, stimulant, utilize, audience, rely, nucleotide, bacterial, button
<table>
<thead>
<tr>
<th>Higher Freq.</th>
<th>Lower Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>area</td>
<td>undefined</td>
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<tr>
<td>chapter</td>
<td>indicate</td>
</tr>
<tr>
<td>data</td>
<td>constant</td>
</tr>
<tr>
<td>factor</td>
<td>plus</td>
</tr>
<tr>
<td>vary</td>
<td>transform</td>
</tr>
</tbody>
</table>

Table 24. Essential Word List (EWL): Academic words.
<table>
<thead>
<tr>
<th>convert</th>
<th>interpret</th>
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</thead>
<tbody>
<tr>
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<td>interpretation</td>
</tr>
<tr>
<td>converting</td>
<td>topic</td>
</tr>
<tr>
<td>item</td>
<td>simulate</td>
</tr>
<tr>
<td>compute</td>
<td>invest</td>
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<td>computation</td>
<td>investment</td>
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<td>option</td>
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<td>generation</td>
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<td>locate</td>
<td>precision</td>
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<td>terminate</td>
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<td>reverse</td>
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<td>grade</td>
<td>proceed</td>
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<tr>
<td>grader</td>
<td>procedure</td>
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</table>
Word list validation

To validate the word lists, I decided to compare their text coverage of TUSK and SMACK against three major word lists: New General Service List (NGSL) (Brown, 2017), Coxhead’s AWL (2000), and Gardner and Davies’s AVL (2013) (see Chapter 2 for a detailed description of these studies). These word lists were chosen because they are the most recent and reliable general and academic word lists that have been used commonly over the last decade. According to the instruction of AntWordProfiler, I compiled the words of NGSL, AWL, and AVL into baseword files, a plain text format document that can be uploaded into the software through the provided option in the setting. I uploaded 1000 word families in each baseword file. I also uploaded a total of 20 baseword files including 19,327 word families. Table 24 presents an overview of the total number of lemmas in each word list and the text coverage that they provide.

Table 25. Text coverage of each word list in this study.

<table>
<thead>
<tr>
<th>Word list type</th>
<th>Total lemma</th>
<th>Total token</th>
<th>Text coverage</th>
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<td>9,808,239</td>
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<td>25,670</td>
<td>0.24%</td>
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<td>430,143</td>
<td>4.06%</td>
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<tr>
<td>Total Corpus</td>
<td>17,565</td>
<td>10,571,059</td>
<td>100.00%</td>
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In order to have a clear profile of the word lists and to make a validated index, I compared the word lists (HF, MF, LF, STEM-related, and academic list) against the three base lines mentioned above in four genres or K-12 content areas of math, science, social studies, and language arts. Table 25 shows that the three frequency word lists provide a higher text coverage than that of NGSL.

Table 26. Text coverage of three frequency lists against NGSL in four K-12 content areas.

<table>
<thead>
<tr>
<th>Corpus genre</th>
<th>Math</th>
<th>Science</th>
<th>Social studies</th>
<th>Lang Arts</th>
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<tbody>
<tr>
<td>Gap (HF – NGSL)</td>
<td>8.30</td>
<td>7.21</td>
<td>5.58</td>
<td>2.07</td>
</tr>
<tr>
<td>Gap (MF – NGSL)</td>
<td>5.51</td>
<td>4.23</td>
<td>4.81</td>
<td>1.10</td>
</tr>
<tr>
<td>Gap (LF – NGSL)</td>
<td>3.01</td>
<td>2.28</td>
<td>1.91</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Figures are in percentages.

As shown in Table 26, the smallest gap superiority is for Language Arts, demonstrating its rich context with respect to high frequency words in general English. However, in math and science we see larger gaps. All three frequency lists outperformed NGSL in the four K-12 content areas. This higher text coverage could be related to the fact that the three frequency lists are directly derived from K-12 textbooks while NGSL is based on a corpus of general English. This higher text coverage shown in Table 26 confirms the validity of the three frequency lists in this study. To validate the academic and STEM-related word lists, I also compared their text coverage of the K-12 corpora against AWL and AVL (Coxhead, 2000; Gardner & Davies, 2013). Results of the comparisons obtained from AntWordProfiler are presented in Table 27.
Table 27. Text coverage of my Academic and STEM-related word Lists against AWL and AVL in four K-12 content areas.

<table>
<thead>
<tr>
<th>Corpus genre</th>
<th>Math</th>
<th>Science</th>
<th>Social S</th>
<th>Lang A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap (Academic word list – AWL, AVL)</td>
<td>1.45</td>
<td>3.20</td>
<td>2.98</td>
<td>4.23</td>
</tr>
<tr>
<td>Gap (STEM-related – AWL, AVL)</td>
<td>1.62</td>
<td>3.73</td>
<td>1.91</td>
<td>3.55</td>
</tr>
</tbody>
</table>

Figures are in percentages.

The gap in four content areas is always larger than 1%, thereby demonstrating the validity of the academic and STEM-related word lists of the present study. Nation (2016) claims that larger gaps show weaker text coverage. Both Tables 26 and 27 show that our word lists have smaller gaps. A further finding from these comparisons substantiates the value of adjusted frequency word lists in making word lists with a relatively high text coverage.

Finally, Figures 6 and 7 demonstrate Zipf’s (1949) law that a small portion of text token covers a considerable part of the corpus. In accordance with Zipf’s notion of lemma offering more bank for the buck, in this research, high frequency and academic words account for approximately 23% of the 17,565 lemmas; however, these two categories have a text coverage of 96.84%, meaning that, learning only these two classes of words will likely provide ELLs with sufficient word knowledge (Nation, 2013) to obtain a successful reading comprehension.
Figure 6. Text coverage vs lemma percentage of academic and high frequency words for the entire corpus.

Figure 7. Academic vocabulary vs STEM vocabulary in TUSC and SMACK by percent.
The rate of STEM words is lower than academic words in both TUSC and SMACK (see Chapter 2 for a typology of vocabulary in this study). However, this might be because I used the AntConc software, and a selective process is still needed to make the final decision about the STEM words and this might change the balance. Figure 6 compares STEM words in TUSC (a general corpus) and SMACK (a specialized corpus) showing the importance of academic words in specialized corpora.

**Essential word list (EWL) considerations**

So far, I developed new academic and essential word lists. Figure 8 displays what I found with regard to K-12 EWL which is re-answering RQ #1 with the K-12 data of this dissertation. As maybe be seen in Figure 8, a good portion of text coverage in both TUSC and SMACK comes from the first thousand most common words. It also shows that basic academic words (only 200 of the first most common lemmas) cover more than 7 percent of the textbooks represented by SMACK. Overall, Figure 8 substantiates the significance of K-12 EWL with respect to text coverage.
Figure 8. EWL by K1, K2, and Basic Academic Words in TUSC and SMACK by percent
CHAPTER V

The mobile app and website: Vocabulary in Reading Study – VIRS

Introduction

We live in a society with an ever growing technological tools and we are becoming more dependent to its applications and uses. Therefore, it is now a high priority in K-12 schools to apply technology to teach content areas and English as a second language, as well. Cristen (2009) writes that with the emphasis that Common Core Standards put on technology in K-12 education, the use of technology in classrooms is essential if teachers hope to have a positive impact on students’ learning and prepare them for the real life situation.

Future research recommended by the National Reading Panel (2017) was the incorporation of computer and mobile apps in reading instruction. Therefore, a key outgrowth of this project is the development of a mobile app—Vocabulary in Reading Study (VIRS), available on the APP Store, Android, and Google Play—and a website (www.myvirs.com). In this respect, I answer the third research question in this chapter, whose focus is on developing VIRS as a mobile app for teaching reading and vocabulary to ELLs.

I have been working with three computer teams in College of Computer Science at FIU from January 2017 to May 2018 to develop VIRS. So far, we have developed three versions of the app and Version 4 is currently under construction. In the first version, we set the foundation of the website and color-coded reading method. In Versions 2 and 3, we
added School Dictionary, iTranslate, Vocabulary Tests, and Profile. In Version 4, we hope to add Essential Word List and improve text analysis.

With the use of the website and the app, teachers are able to analyze any type of text which may be sifted through OCR technology to create a vocabulary profiler. The app synthesizes the academic vocabulary found in K-12 textbooks and features an enhanced reading method that expedites the L2 reading process using a color-coded system.

The app uses six categories for sifting the words: high, mid, and low frequency words, STEM-related and academic words, plus a category for names and off-lists. Therefore, teachers can use VIRS in choosing the appropriate reading texts to work on in their classes.

Figure 9. The home page of the app – VIRS.

In addition, teachers can sign in by creating a user name and password. This way, all teachers can have their own profile to save their data for future use. The option from which
teachers can benefit is the readability measurement function which analyzes the text. VIRS has the following features:

1. It produces enhanced texts through a color-coded system.

2. It gives a detailed analysis of texts that will help K-12 teachers develop course materials, and

3. It helps teachers to take a picture of a text through OCR technology and then sifts it through a vocabulary profiler,

The current version of VIRS also has six vocabulary tests for all proficiency levels from beginner to advanced. Each test has 100 questions that randomly scramble each time the user starts a test. Two out of the six tests are Nation’s Vocabulary Size Test (Nation, 2001) that I divide them into two versions of A and B. Other main functionalities of VIRS include:

1. VIRS analyzes texts quickly in four different input modes.

2. It raising students’ awareness to different word categories such as academic and STEM-related words through a different color.

3. It gives a result table for vocabulary tests and recommends on what to do next,

4. It has a pop-up dictionary that hopefully makes the reading for ELLs easier and quicker, and

5. VIRS has an online translation tools that saves users’ time.
Overview of tools

VIRS has four tools for analyzing texts, improving reading, and conducting corpus linguistic research. These tools are a) Analyze your text, b) School dictionary, c) vocabulary tests, and d) iTranslate. Analyze your text is designed to be used by teachers for material development, the other tools may be used by ELLs in classroom or while doing self-study. Below, I will explain each tool in order.

Analyze your text

This tool allows teachers and ELLs to upload texts and then the app turns it into enhanced text. There are four modes for uploading texts: type the text (max 30,000), word document files (max 5 MB), PDF files (max 25 MB), and image files (max 25 MB).

Figure 10. Color-coded system for reading comprehension
By pressing the Enhanced Text option, VIRS analyzes the text and presents in a different page in a color-coded enhanced format. Each word has a different color such that ELLs will hopefully be more engaged in reading processes.

An important feature of enhanced texts is their link to a pop up dictionary such that the meaning of the word pops up by clicking or touching the word. This way ELLs do not need to search every word in a dictionary that helps save time and energy. Also on this page is a detailed statistics of the uploaded text, including the number of academic and STEM-related words as well as high frequency vocabulary.

School dictionary

I used the K-12 corpora, TUSC and SMACK, to compile a new school dictionary which may make it easier for students to learn new vocabularies while reading their textbooks through VIRS. This is a frequency-based dictionary which categorizes words into five categories of lemmas which are in harmony with the color-coded system in the enhanced text option. The five categories include high (3,750 lemmas), medium (5,030 lemmas) and low frequency vocabularies (8,089 lemmas), academic words (423 lemmas), and a section for STEM-related words (238 lemmas) as well. In total, our school dictionary has 16,500 lemmas plus derivational and inflectional forms.
Pilot vocabulary tests

There are six test categories in this tool through which ELLs can check their vocabulary knowledge. Tests are ordered in terms of difficulty from beginner to advanced level (Cambridge vocabulary tests, 2016). Also, there are two versions of Nation’s (2013) Levels Test. Each test has a different number of questions that will be shuffled each time an ELL takes the test so that the chance of having repeated questions will be low. For each question, ELLs will have 60 seconds to answer. Test results will be presented in a table alongside some recommendations based on the ELL’s score on the test.
iTranslate

The iTranslate tool is linked to Google translation (www.translate.google.com) and has the same function, as well. Its purpose is to save ELLs time and make the reading easier. This tool allows ELLs to switch to their native language while reading on VIRS help them scaffolding reading through translanguaging (Nation, 2016).
Figure 13. iTranslate home page.
CHAPTER VI

Teaching-learning implications of this dissertation and conclusion

Synopsis

For this dissertation, I created two corpora—The Teacher’s U.S. Corpus (TUSC) and the Science/Math Academic Corpus for Kids (SMACK); six word lists emerging from these corpora—high frequency, mid frequency, and low frequency words, as well as lists for academic words and STEM-related words, and an Essential Word List; and a mobile app which is synchronized with a website offering four main tools (text analysis, school dictionary, vocabulary tests, and iTranslate).

I created the two corpora, and then based on Cobb’s LexTutor, I developed a profile of textbooks for the States of Florida and California. The main findings of this dissertation are as follows:

1. I developed a new typology of vocabulary knowledge including K-12 STEM-related words (Chapter 2).
2. I developed a new model for developing vocabulary knowledge based on mental process (Chapter 2).
3. The text coverage of academic vocabulary in Florida and California K-12 textbooks is 4.12%, which is way lower than recommended 10% used in college texts (Chapter 4).
4. Based on proportions of academic vocabulary, Social Studies seemingly uses the most difficult language, while Language Arts employs the easiest (Chapter 4).
5. I created the largest K-12 STEM-related and academic corpus to date, SMACK, with more than 8 million words (Chapter 4).

6. All five word lists are more valid than the NGSL, AWL, and AVL (Chapter 5).

7. High frequency words cover 91.81% of K-12 textbooks; meaning, that ELLs can survive in school with only 3,750 lemmas (Chapter 5).

8. The high frequency words with about 3,750 lemmas include both the essential and survival words that ELLs need to survive in school (Nation, 2016) (Chapter 5).

9. For having a better comprehension in K-12 content areas, focusing on domain-specific words, both academic and STEM-related word lists, can likely improve ELLs’ text coverage (Chapters 3 and 5).

10. I developed a new K-12 dictionary that is specifically designed for ELLs (Chapter 6).

**Implications for teaching English as a second language in U.S.-based schools**

**Course design**

Setting realistic language learning goals is an important part of designing a course. There is a rich line of research on text coverage (Nation, 2006; Nation, 2013; Schmitt & Schmitt, 2014) that has suggested low, mid, and high frequency levels considered as learning goals for ELLs. Thus, the six word lists developed in this study, as well as the two corpora, may hopefully provide K-12 teachers and textbook writers with a guidelines about which words and how many are needed at different learning stages for ELLs. However, this needs further research to be confirmed statistically.
Nation (2013) claims that, in designing a course, high and mid frequency words are taken as receptive vocabulary knowledge learning goals for learners who want to use it for everyday purposes. In this study, however, the high and mid frequency words are more than 8,000 lemmas that ELLs need to survive through K-12. Nation (2016, p. 172) believes that textbook writers and course designers do not use word lists and vocabulary levels systematically. This is why he thinks that the influence of word lists in K-12 curriculum development is uncertain. Designing an effective course for ELLs in K-12 requires using an appropriate word list which is driven out of K-12 textbooks that meet the needs of ELLs.

**Reading material development for ELLs**

While ELLs read for the purpose of understanding messages, incidental vocabulary acquisition from meaning-focused input may happen. Appropriate materials can expedite this process (Hulstijn, 2001). In the selection process and preparation of such reading materials for ELLs, word lists can have a central role. The word lists in this study may provide teachers with a tool from which they can select the words that ELLs should develop first. For those ELLs in content areas who are beginners in academic English, the STEM-related and academic word lists of this study are resources that ELLs can start with as a precursor before learning AWL and AVL. Range and AntWordProfiler (Webb & Nation, 2008) are also other tools but with different functionality that teachers can use.

**Readability measurement for ELLs**

With using three text analysis programs (VocabProfiler on Cobb’s Lextutor, AntWordProfiler, and Range – see Chapters 4 and 5 for the description of these programs),
there is an upward trend of research on the different types of vocabulary load of texts ELLs read. For example, VocabProfiler is a tool on LexTutor that analyzes a text with respect to frequency level and academic words as well. The program determines the frequency level of words and which and how many are off-list. In the next step, the program makes a judgement on the difficulty level or vocabulary load based on the proportion of text tokens at the low frequency or off-list levels.

Such programs and other research carried out on vocabulary load depends on well-researched word lists. List makers fortunately share their lists freely through publications or websites and this may improve the quality of readability measurement tools.

**Developing K-12 vocabulary tests**

An area affected the most by the use of word lists is vocabulary tests. In developing the vocabulary size tests (Nation & Beglar, 2007; Coxhead, Nation & Sirn, 2014) BNC and COCA have been used. Schmitt, Schmitt and Clapham (2001) and McLean and Kramer (2015) also used AWL for the vocabulary test development. With respect to levels tests (McLean, Kramer & Beglar, 2015), BNC and COCA word lists were also used.

The difference between size and levels tests has always been misunderstood by language teachers. While vocabulary levels tests measure ELLs’ vocabulary knowledge of a particular level, size tests focus on the ELLs’ total word knowledge. For designing a language course, Nation (2016) believes that levels tests are more beneficial because they measure the actual words that ELLs need to know. The original levels tests are mainly based on Thorndike and Lorge’s (1944) list, which is pretty old. There are now better and updated lists that could be used for developing new levels tests. In this regard, three of the
word lists I developed through this study focus on three frequency levels that could be used for developing the K-12 levels test. Meanwhile, an appropriate vocabulary test has to use a sample of the words that represents the whole language. Dictionaries were the main source for such samples, but Nation (2013) claims that this sampling method results in a sampling error. He believes that word lists provide the best word samples because they are corpus-driven. As a result, the word lists of the present study may provide teachers and researchers with reliable samples for vocabulary test development. Furthermore, teachers may substitute the items of depth of vocabulary knowledge test (Read, 2000) with the items of the word lists to measure depth dimensions of word knowledge.

**Classroom activities that focus on word lists in teaching vocabulary to ELLs**

In this section of teaching-learning implications of the word lists that I developed in this study, I present some classroom activities that might help both teachers and students focus on words from the K-12 word lists. Each activity comes with a brief description and implementation in class, followed by some suggestions for how to modify it according to the needs of ELLs. My focus is on how to use these vocabulary instruction activities with the lists that I developed in this dissertation; however, these activities may also be applicable to other lists and learning contexts.

**Frayer model**

Frayer, Frederick, and Klausmeier (1969) developed the Frayer Model, which applies the graphic organizer technique to let students explore the deeper aspects of
meanings of the words in word lists. Through the tasks below, Frayer et al. found that students are able to clarify their understanding of the target words:

- Identifying the examples and non-examples of the meaning, and
- Identifying the essential and non-essential characteristics of the word in a particular word list.

**Implementation**

As such, through the implementation of VIRS – and indeed the word lists coming out of TUSC and SMACK – students may be able to

- Identify the target words from a word list, for example, some basic words such as tissue, cell, organism, atom from the Science sub-list of the STEM-related word list.
- Distribute the model’s graphic organizer among student (this is available online).
- Brainstorming for completing the areas of the graphic organizer using the words from the lists.
- Ask students to make their individual graphic organizers with other similar words.

**Word sorts**

A word sorts is a hands-on activity (Gillett, Temple, & Crawford, 2004) that seemingly improves ELLs’ manipulating academic or STEM-related words into different groups of other words based on relationship or function. Teachers may use this activity to make comparisons between domain specific words to improve ELLs’ word analogy.
Implementation

- Choose 10-20 words from a word list which are related to the discussed topic.
- Choose between open or closed sort and then model word sorting for students.
- In small groups, ask ELLs to sort words based on the domain or word list the word is belong to. Then show the word in the original list and ask them to discuss.

Triple-entry vocabulary journal

The triple-entry vocabulary journal is a version of dual-entry diary (Berthoff, 1981) that teachers may use to help students make connections between words across different word lists. By using this activity, teachers can also communicate with their ELLs through feedback on their entries. Meanwhile, this activity can be used as a personal record of word list learning.

Implementation

- Choose a number of words from a particular word list that appear frequently in a topic that is discussed in class.
- Provide a template for this activity with three columns titled sentence in text, word, and my thought.
- According to the chosen words from word lists, ask ELLs to complete the Triple-entry vocabulary journals
- Share ELLs’ thoughts and then give feedback
Semantic feature analysis

A semantic feature analysis uses graphic organizers to improve ELLs’ understanding of similarities and differences between academic and STEM-related words (Schmitt, 2000). Therefore, this activity will be effective for teaching synonyms or antonyms. Also, this activity will be a good choice for teaching similar or opposite concepts.

Implementation

- Identify the words from word lists that represent similarities or differences, for example, a comparison between physical and chemical changes.
- Prepare a graphic organizer with the words and display it on the board.
- Present the words to ELLs and then discuss the similarities and differences.

Identifying cognates

Because of the same Latin roots, there are many Spanish-English cognates in English academic words (Nation, 2013). Bushong (2010) identified several Spanish-English cognates on AWL. The same is also true about the word lists of this study. This activity will be especially helpful for Spanish-speaking ELLs by making them aware and teaching the cognate recognition strategies through using the word lists.
Implementation

- Introduce cognate to ELLs and explain that they can use their knowledge in Spanish to understand English texts.
- Work with students on a cognate pair from a word list.
- Ask students to use the words from the list in both languages.

General implications for teaching English as a second language

Word cards and flash cards

Vocabulary learning activities with word lists sometime is misunderstood with the idea of memorizing words from list of words which is out of context and is technically known as rote learning. However, learning words from word lists through doing activities such as word cards or flash cards has proven to be effective learning tools (Nation, 2013, 2016), if the right words chosen appropriately.

Nation (2013) suggests that using flash or word cards based on a well-designed word list is a kind of intentional vocabulary learning that will subsequently lead to learning the studied words. In Chapter 11 of his book, Nation (2013) reviews the research in support of using flash card apps. With respect to the findings of this study, the word lists may be used in developing flash cards for ELLs. In addition, developing the flash cards based on the STEM words from this study can help ELLs in ESP courses.

Learners' dictionary

An important tool in the app which is a direct outgrowth of the word lists is the K-12 dictionary. There is no doubt that a learners’ dictionary has significant effect on
ELLs’ overall proficiency (Nation, 2013). With respect to this study, the six word lists developed may be used to annotate properly the words in the four content areas. A further application of the word lists in developing a K-12 learners’ dictionary is the construction of well-controlled definitions for the words because many words have different meanings some of which are irrelevant to the K-12 context and by the use of K-12-based word lists we can determine the most relevant meanings that ELLs need to first learn.

**Designing graded readers**

Graded readers are books written within a specific level of word frequency with the intention of improving ELLs’ vocabulary and finally their reading comprehension (Nation, 2001). Graded readers have a specific vocabulary scheme for each proficiency level. However, there are not well-designed graded readers for ELLs in the K-12 context and the sub-lists I developed in this study will lead to the integration of K-12 word lists into different series of graded readers.

**Limitations of this project**

A number of limitations regarding this project are worth mentioning:

1. The main limitation of this study is the size of the corpus and number of books. The two corpora involves books from California and Florida. Due to time, budget, and other resource limitations, I couldn’t collect textbooks from other states especially New York and Texas, which are two main educational centers textbook companies often look to. A further related issue is the size of the corpora (more than 10 million
in total) which is not a satisfactory size for making fair claims, as De Gardner and Davies (2013) believe that a way bigger corpus is needed to confirm the claims.

2. The second limitation of this study is the lack of grade by grade analysis of the four content areas with respect to vocabulary classification. This was mainly because of time limitation and it will be top on my research agenda for future research.

3. Because of the problems that I had in collecting the textbooks, the corpus is skewed toward middle and high school textbooks. This issue, however, will be solved by adding more K-5 science and social studies textbooks.

**Directions for future research**

For further research on corpus-driven and word list studies, there are various directions that I recommend:

1. Application of word lists based on frequency or so-called efficiency over time has never been fully researched. In other words, a frequency-based curriculum is needed in order to teach vocabulary in a need-based order. This line of research could also be extended to textbook development and syllabus design.

2. Corpus development for making a word list should be in accordance with the needs of the target audience and their language uses. Also, all corpora are only a rough representation of the actual needs of ELLs, especially in K-12 context, a research study is needed to focus on dispersion rather than frequency.

3. A readability index particularly designed for ELLs’ texts is a needed research that has not been developed yet. This should be an interdisciplinary research with a team
of statisticians. This readability measurement will be of great help to course developers and classroom teachers in choosing the appropriate reading materials.

4. TUSC is a Florida general corpus with more than 3 million word and SMACK is an academic corpus which is skewed toward middle and high school. Both corpora represent textbooks from States of Florida and California. Future research can focus on developing word lists based on larger and more comprehensive corpora. This way, the claims made by word lists will be more generalizable to K-12 school system.

5. A validated vocabulary test based on the current word lists is needed. Such a test which will be based on analysis of K-12 textbooks will help designing a curriculum for ELLs that best matches their needs.

6. There has never created a spoken corpus for ELLs in K-12 context. Developing such a corpus for improving learners’ fluency is needed. Developing well-designed reading materials accompanied with audio files will also be beneficial for improving ELLs’ fluency.
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