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Textbook Vocabulary Knowledge Amongst Engineering Majors in Taiwan

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Textbooks play a major role in learning. It therefore follows that a lack of required vocabulary amongst university students may lead to inadequate reading comprehension thus directly influence the development of their professional knowledge. In order to help engineering students expand their vocabularies to a satisfactory level, this study was undertaken to investigate the level of vocabulary knowledge required for successful textbook comprehension. A corpus, including 10 commonly used textbooks in the School of Engineering, was compiled as an instrument. 3,941 required words were then selected to create a Fundamental Engineering wordlist (FEW). The FEW was further divided into general service, academic, technical, and supplementary word categories. A vocabulary test was carried out amongst 124 engineering students to measure their receptive knowledge of the vocabulary on the list. The results of the study revealed that (1) students recognized 60% of the words on the FEW; (2) in terms of the word categories, the participants were able to recognize 80% of general service words, 60% of academic words, 47% of the supplementary and 40% of the technical words, and (3) the main difference between freshmen and sophomores lay in their knowledge of the subject-related vocabularies (supplementary and technical), rather than that of the non-subject-related vocabularies (academic and general service).

Keywords: EAP, textbooks, wordlist, vocabulary knowledge, engineering major

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INTRODUCTION

Vocabulary learning has been an important part of English language education. However, after years of English learning, English learners still display inadequate vocabulary storage when reading content-area textbooks (Nurweni & Read, 1999; Parkinson, Jackson, Padayachee, & Kirkwood, 2007; Ward, 2001).In Taiwan, textbooks serve as the single most-used classroom material in English classrooms (Chang, 2006). They provide an important input of the target language for students and the main source of support for teachers, most of whom lack native-like competency. Given such tradition, it might be worthwhile to look into textbook content and examine the vocabulary required for comprehension.

The focus of the present study is to uncover the vocabulary required for textbook comprehension and explore the quantity and quality of students' vocabulary repertoire. The current discussion on vocabulary knowledge focuses on engineering majors. The reasons being that first, Taiwan has prided itself as one of the world's leading designers and manufacturers of technological products. Each year thousands of engineering students graduating from universities and graduate schools enter the job force; however, a survey indicates that 49% of engineers consider their English abilities poor and inadequate for use of English in the workplace (Lu, 2009). Second, in the university under study, the student body of engineering majors represented around 45% of the total student body. Although they make up the largest group on campus, engineering majors showed the lowest achievement in TOEIC reading test conducted in 2009. First-year students in the engineering departments scored 233 (full score 495), below the total freshman average of 253, yielding a need to investigate the insufficient components of vocabulary knowledge for the engineering students.

Difficulties in Reading English Content-Area Textbooks

Due to the lack of suitable content-area textbooks written in the learners' native language (Chang & Lin, 2000; Chen, 2002; Ward, 2001), reading English textbooks is requisite and a main method of acquiring domain-specific knowledge for most L2 learners (Jackson, Meyer, & Parkinson, 2006; Parkinson & Adendorff, 2004) or EFL students (Ward, 2001), especially for those at the university levels. However, studies have found content-area reading difficulties for non-native English students (Prins & Ulijn, 1998; Ulijn & Salager-Meyer, 1998) and such difficulties may be attributed to three main factors: (1) inadequate domain-specific knowledge, (2) cultural differences between writers and readers, and (3) insufficient language competence. Insufficient language competence serves as a basic assumption in the current investigation on the reading difficulty of engineering majors in Taiwan.

In terms of language competence, previous researchers (Nurweni & Read, 1999; Prins & Ulijn, 1998; Ward, 2001) found the lack of vocabulary recognition to be a great hindrance in comprehending content-area textbooks. Similar to college students in many EFL countries, Taiwanese university students are assigned to read English content-area textbooks due to the paucity of the textbooks written in Chinese (Chang & Lin, 2000; Chen, 2002); moreover, reading obstacles, especially difficulties in recognizing unfamiliar words and phrases, have kept them from textbook comprehension(Chen, 2002).

Required Vocabulary for Comprehending a Reading

Several assumptions about sufficient vocabulary size for L2 language learners have been proposed. The first assumption assumed that L2 learners should know all of the words in the target language, including approximately 110,000 word families (Nagy & Anderson, 1984). The second assumption proposed that L2 learners needed to know as much vocabulary as native English speakers, including about 17,000 word families (Goulden, Nation, & Read, 1990).The third assumption took reading activities into serious consideration and proposed that an L2 learner ought to know enough amount of vocabulary that he or she could use of in reading tasks such as reading a content-area textbook. In this case, the estimated target was approximately 3,000 to 9,000 word-families, depending on the target genre. Other researchers were concerned with the relationship between text coverage and reading comprehension (Hirsh & Nation, 1992; Hu & Nation, 2000; Nation, 2006). Text coverage refers to the percentage of running words in the text that readers know. Although the figure of 95% coverage was suggested by many researchers (Hirsh & Nation, 1992; Laufer, 1985; Ward, 1999) to be a minimum “threshold” for achieving an adequate level of reading comprehension, Hu and Nation (2000) noted that 98% was clearly better for pleasure reading. In this study, the researchers agreed with the majority of the researchers and decided 95% coverage to be the criterion for reading comprehension.

Engineering Wordlists

Wordlists specify what and how many words learners need to learn in order to perform reading tasks. Many language instructors, material designers and test developers do their work based on reliable wordlists. It is now agreed that the specialized wordlist is a clear learning objective, presenting the vocabulary requirement to L2 learners of the discipline (Coxhead & Hirsh, 2007; Hwang & Nation, 1995; Hyland & Tse, 2007). To date, only a few researches have studied engineering wordlists and three have been devised: (1) Engineering Word List (EWL) by Ward (1999), (2) Basic Engineering List (BEL) by Ward (2009a), and (3) the Student Engineering English Corpus (SEEC) by Mudraya (2006). These wordlists have helped students learn the required vocabulary knowledge of the discipline.

The EWL was an engineering wordlist of 2,000 word families (about 6,000 word types) from a five-textbook corpus of more than one million running words. In 2009, Ward again created a 299-word-type basic engineering wordlist (BEL) for Thai engineering students. The BEL was based on a corpus of around 271,000 running words that contained 25 textbooks commonly used in students' 3rd and 4th years at Suranaree University of Technology in Thailand. The SEEC, was a frequency-based wordlist of 1,200 word families (approximately 8,850 word types) derived from a corpus of about two millions of running words, which contained 13 textbooks used in 9 basic engineering disciplines at Walailak University in Thailand.

There is no doubt that these wordlists can provide clear learning targets for engineering majors. However, it is debatable whether these wordlists can be generalized and applied to the Engineering majors in Taiwan. As Rizzo (2010) recommended, the size of a specialized corpus should be as big as possible and that the proportion of each text in the corpus should be equal and balanced. However, the corpus size for some disciplines was several times bigger than others in Mudraya's wordlist. Moreover, the purpose of Ward's (2009a) study was to find out a number of basic engineering English words for less proficient engineering undergraduates. As a result, merely 299 word types were listed in the BEL which made up only 16% of the running words in Ward's BEL corpus. This percentage was away from the threshold (95% text coverage) that this study aims for.

Finally, Taiwan and Thailand differ in terms of compulsory disciplines. Table 1 presents the basic engineering courses in the EWL, the SEEC, and the current study. Specifically, Calculus, General physics, and Engineering Mathematics are compulsory for Taiwanese students in the School of Engineering but these disciplines are not found in the SEEC. On the other hand, Electrical Engineering is not included as a member of the School of Engineering in Taiwan.

Table1 *Courses included in the EWL, the SEEC, and the current study*

	EWL	SEEC	Current study
1	Engineering Thermodynamics	Computer Programming	Advanced Engineering Mathematics
2	Engineering Mechanics	Electrical Engineering	Applied Mechanics
3	Fluid Mechanics	Engineering Drawing	Calculus
4	Mechanics of Materials	Engineering Materials	Engineering Drawing
5	Statistics & Probability	Engineering Mechanics	Engineering Mathematics
6	-----	Mechanics of Fluid	General Chemistry
7	-----	Mechanics of Materials	General physics
8	-----	Manufacturing Process	Introduction to Computer Science
9	-----	Thermodynamics	Mechanics of Fluid
10	-----	-----	Mechanics of Materials
11	-----	-----	Numerical Analysis

Note. All the courses are listed under alphabetical order.

Word Counting Units

For the purpose of the study, four kinds of word counting units are examined, including: word tokens, word types, word lemma, and word families (Nation, 2001). Word tokens, also called running words, indicate individual words in a text. If the same word occurs twice, each occurrence will be counted as one token. Word types, on the other hand, refer to every different word in a text. In this case the same word will be counted only once. Lemma is composed of a headword and some of its inflected forms. The lemma is usually used as the word counting unit in dictionaries. Lastly, word family represents a set of related words, which consist of a headword, its derived forms, and also its inflected forms. For example, the word family of the headword “*touch*” covers a number of inflected forms (e.g., *touching*, *touched*, and *touches*) and derived forms (e.g., *touchable* and *touchy*).

Although word family and lemma were often used in research, they have their drawbacks. Schmitt and Zimmerman (2002) do not recommend using word family as counting units of words. They found that ESL learners usually have only partial knowledge of derivatives. Additionally, Ward and Chuenjundaeng (2009) also claimed that the EFL students were at a great disadvantage when it came to morphological analysis, especially learners with lower proficiency levels. They either had insufficient information for morphological analysis or they did not understand the significance of the affix. As for the word lemma categorization, Ward (2009a) found that EFL learners had inadequate grammatical knowledge to distinguish the inflected forms, such as *-ed* and *-ing*, in different lexical environments. In addition, the findings in Ward’s experimental study on the BEL did not support the use of lemma. Ward (2009a) noted that different word types within the same lemma had different distribution profiles. For example, in spite of the fact that all three word types belong to the same lemma, *balance* and *balanced* were more essential for engineers than *balances*.

Thus, the current study decided to select word types as the word counting unit in understanding the vocabulary knowledge of engineering majors in Taiwan.

Word Classifications

On the basis of Nation’s definition (2001), there are four categories of vocabulary in a text: high-frequency words, academic words, technical words, and low-frequency words. In this study, the classification starts with the identification of technical words because it is acknowledged that technical words are domain-specific words, ranging from high-frequency words to words with lower frequencies. Similar with Chung and Nation (2003) and Nation (2001), this study differentiated technical words from non-technical words on the basis of word form and word meaning. To be more precise, technical words are subject-related. Although such word form can be shown both inside and outside the field of engineering, its meaning is specific to engineering. For example, *induced*, *flux*, *terminal*, *earth*, *anode*, *impedance*, and *dielectric* are technical words in Electronics (Nation, 2001).

On the other hand, non-technical words are non-subject-related words. General Service words and academic words belong to this category. General Service words, termed as high frequency words in Nation's categorization, are basic English words that are of service no matter what the language is used to do (Nation, 2001, 1990). Function words, such as *the*, *of*, *about*, and *this*, and unmarked content words, like *things*, *parts*, and *show*, are included in this category of vocabulary. General Service words can be used both inside and outside the field of engineering and the meaning of the word is not specified. West's (1953) General Service Wordlist (GS), including 2,000 basic word families of English, is often used as reference for the words of this category. Academic words, sometimes called semi-technical words or sub-technical vocabulary (Nation, 2001), are not restricted to a specific discipline and are useful for learners pursuing academic studies. Nowadays, the most used academic wordlist is the Academic Wordlist (AWL), which includes 570 word families, compiled by Coxhead (2000). The concepts of academic words are more abstract than subject-related words, but they allow the writers to provide support for, or explanations of, the subject matters.

The Purpose of the Study

Although previous studies have created wordlists for related fields of engineering (Mudraya, 2006; Ward, 1999, 2009a, 2009b), no study ever analyzed students' knowledge of the relative vocabulary list. The researchers of the study believe that the examination of both quality and quantity of gained vocabulary knowledge may shed light on what words are required for engineering students and how their vocabulary learning can be facilitated. Thus, the purposes of the study are to first compile a list of required words for comprehending textbooks and then to examine the quantity and quality of student knowledge on these required words. Specifically, the research questions of the current study are as follows.

- How many words on the Fundamental Engineering Wordlist (FEW) do the participants recognize?
- Does students' receptive word knowledge differ in the four word categories?

METHODOLOGY

Corpus Design

In order to compile a representative corpus of Engineering English textbooks, the researchers first surveyed the fundamental disciplines required of engineering students in their first two years of study. As a result, 11 courses were found. Of the 11 courses, three (Calculus, General Physics, and Engineering Mathematics) were compulsory courses for all engineering majors. On average, all engineering majors in Taiwan were required to take at least eight out of these 11 courses in order to graduate. However, of the 11 disciplines, only ten English textbooks (Appendix 1) were frequently used since other courses used mostly Chinese translation of the English textbooks.

Table 2 *The structure of the FEW Corpus*

N	Text File	Bytes	Tokens	Types	Type/ Token Ratio	Average Word Length	Proportions in Corpus
1	Calculus.txt	539,955	86,648	2,399	2.79	4.60	10.70%
2	Eng_Math.txt	501,165	77,798	3,927	5.07	4.75	9.63%
3	Physics(1).txt	345,669	56,299	4,138	7.37	4.67	13.52%
4	Physics(2).txt	319,839	52,928	4,376	8.30	4.72	
5	Chemistry.txt	535,990	83,540	5,787	6.96	4.94	10.34%
6	Fluid_Mech.txt	624,122	99,561	5,134	5,.17	4.76	12.33%
7	Intro_Comp.txt	700,448	104,999	4,486	4.28	4.95	13.00%
8	Numerical.txt	548,389	91,265	4,107	4.54	4.65	11.30%
9	App_Mech.txt	419,305	69,156	2,727	4.02	4.64	8.56%
10	Material_Mech .txt	530.378	85,774	3,185	3.76	4.66	10.62%
	Overall	5,064,410	807,380	15,482	1.93	4.75	100%

After the ten textbooks were chosen, a frequency-based word list was generated using WordSmith tools 5.0. Theoretically, it is ideal to compile a corpus using entire textbooks. By doing so, researchers are free from the concerns about the sampling issues (Mudraya, 2006). Nevertheless, this study could not afford to build up such a large corpus due to the availability of electronic contents and constraint of copyright issues. Thus, in order to recruit as many pages as possible within limited time span, this study drew a systematic sample by selecting every 10th page as a constant. According to Ye (2002), systematic sampling is easier and more effective than simple random sampling (Ye, 2002). The structure of the corpus is summarized in

Table 2. The farthest right-hand column shows the word-token proportion of each discipline in the corpus. The figures range from 8.6% to 13.5%. Although slight differences are found, the sampling in this study is much more balanced than that in the previous studies.

Finally, 3,759 high-frequency content words were selected as they achieved over 95% text coverage. More specifically, they accounted for more than 767,000 tokens in 807,380runningwords. Each word type occurred at least 12 times in the corpus and was thus considered as must-know words for reading engineering textbooks. To be exact, 3,941 word types made up 95.52% of the running words (771,209 tokens) in 807,380 running words were selected originally, including 67 function words and 115 abbreviations, proper nouns, and unit terms. Since abbreviations, proper nouns, and unit terms were not consider as real words and the function words were easy to students, the discussion of the current study focused only on the 3,759 content words.

Word Classifications

In order to ensure the quality of the word classification, the classification procedure was divided into three phases: (1) technical word classification, (2) technical word confirmation and (3) comparisons with Coxhead's AWL and West's GSL to identify academic and general service words.

The first two steps were executed by three postgraduates from the Engineering School (two master students and one doctoral student) and two professors in the School of Engineering. The three postgraduates for the technical word classification came from three different sub-areas: a second-year master student in Mechanical Engineering at the university under study; a graduate from the department of Civil Engineering at the same university; a doctoral student in the department of Material Science and Engineering at a distinguished college in England.

Cohen's Kappa, the measure of inter-rater reliability, was performed afterward. Cohen's Kappa is usually used as a tool for measuring the agreement between two raters on a nominal scale. It is widely acknowledged that the value of the Kappa fluctuates between 0 (if there is no agreement) to 1 (if there is complete agreement). Krippendorff (2004) suggested that a Kappa coefficient above .80 is usually considered to have good reliability; however, values from .67 to .80 are sufficient for researchers to draw a tentative conclusion. In the current study, the inter-rater reliability of the three raters shows a high degree of agreement, ranging from .735 to .760 (Table 3).

Table 3 *Inter-rater reliability of technical word classification*

Raters	Mechanics	Civil	Material
Mechanics		.735	.759
Civil	.735		.760
Material	.759	.760	

Finally, 831 words were identified as technical words by the three raters, including 48 abbreviations (e.g. *ODE* for ordinary differential equation), domain-specific terminologies (e.g. *cantilever*, *isothermal*, *stoichiometry*), unit terms (e.g. *mols*, *kips*, *torr*), and proper nouns (e.g. *Bernoulli*, *Legendre*). The 831 technical words were then sent to the two professors (Mechanical Engineering and Material Science and Engineering) for confirmation. Reliability check between the two professors received a score of .702, indicating that there was substantial agreement. However, both professors suggested discarding the abbreviations (e.g. *ODE* and *Chap*), unit terms (e.g. *torr* and *kips*), and proper nouns (i.e. *Bernoulli* and *Legendre*) from the technical category because these orthographical items were not considered ordinary English words. Thus, 783 of the 831 technical words identified by the three graduate students were confirmed by the two professors.

After the technical words were identified, the rest of the word items were further compared with AWL and GSL to identify academic and general service words. Word items falling outside technical, academic and general service word categories were labeled Supplementary (SUP). SUP words share some characteristics with technical words because they are more relevant to the development of the contents in the textbooks than academic words and general service words (Nation, 1990; Vidal, 2003). Table 4 below describes the proportions of the four word categories in the FEW. It is worth noting that the function words, abbreviations, unit terms, and proper words are ignored in the FEW. Please see Appendix 2 for the sample items in the FEW.

Table 4 *The proportions of the four categories in the FEW*

Category	Content Words	Proportion in FEW
GS	1,695	45.09%
AW	616	16.39%
TECH	783	20.83%
SUP	665	17.69%
Sum	3,759[a]	100.00%

Note.
a. Function words, abbreviations, proper nouns, and unit terms were excluded
b. GS = general service; AW = academic words; TECH = technical; SUP = supplementary

The Vocabulary Test

The yes/no vocabulary test is a promising method for exploring the vocabulary size of ESL/EFL students (Barrow, Nakanishi, & Ishino, 1999; Huibregtse, Admiraal, & Meara, 2002; Ward, 2009b). Students' vocabulary knowledge can be inferred on the basis of their performance on such vocabulary test. It is worth noticing that the yes-no vocabulary test in the current study does not measure the total vocabulary size of L2 learners. It measures their knowledge of the most frequent word types shown in FEW. There were two important components in the yes/no vocabulary test: real words and pseudo words. Pseudo words phonologically and orthographically followed the constraints of English but have no meaning in reality. The use of pseudo words was to avoid overestimating the vocabulary size of the test takers.

With regard to the test items in a vocabulary test, Nation (2001) suggests it is appropriate to choose every Nth word (N is a constant) depending on the number of test items in need. He mentions the figure of 30 items is probably a minimum for a vocabulary test, which measures respondents' knowledge in 1000 words. That means each test item represents 33 words in the 1,000 target words. Using this technique, each category of vocabulary is a different stratum, and each stratum is sampled using a random systematic sampling technique (Ye, 2002). The benefit of stratified sampling is that it avoids sampling bias as the sampled test items adequately represent the four categories of vocabulary in the FEW.

Therefore, each of the four strata was sampled one by one. The study chose every 16th word in each stratum after the first word was determined using a randomization device (i.e., 4, 20, 36, 52…). Since all words were selected randomly and systematically, the vocabulary test contained verbs, nouns, adjectives, and adverbs. Noticeably, words in each stratum were listed from high frequency words to low frequency words. Owing to the merits of the frequency order, both high and low frequency words had equal opportunity to be selected for the vocabulary test. Consequently, there were 240 words sampled: 107 GS words, 39 AW words, 42 SUP words, and 52 TECH words.

With regard to the number of pseudo-words in need, studies suggest that the ideal proportion of real words to pseudo-words is 2:1 (Beeckmans, Eyckmans, Janssens, Dufranne, & Van de Velde, 2001; Ward, 2009b). Following this practice, the current study inserted 120 pseudo words in the vocabulary test. Three methods were used to construct the pseudo-words (Barrow et al., 1999): (1) changing one or two letters of a real English word, (e.g., *root* into *roat*); (2) adding an affix to a base form (e.g., "*shafter*," adding the affix "*-er*" to the base form "*shaft*"), and (3) creating English-like non-words (e.g., *muttle* and *meletrode*). These pseudo-words were used to detect respondent bias (i.e. to determine whether the students take responsibility for and show confidence in their answers) (Barrow et al., 1999; Nation, 2001; Ward, 2009b).

Eventually, 360 test items were created (240 real words interspersed with 120 pseudo-words) on the yes/no vocabulary test (See Appendix 3 for sample items). With a fear that the 360-item vocabulary test might cause fatigue effects (Ward, 2009b), the researchers used Ward's suggested vocabulary size of 180 items. Thus, the 360items were split into two equivalent versions. Each version included 180 test items (120 real words and 60 pseudo-words). The two versions had approximately the same proportions of the four word categories (Table5). It was planned that test takers would complete both versions, and students' vocabulary sizes would be estimated on the basis of their performances on the two versions. As a result, the data collecting process lasted for two weeks: one version was given each week for 15 minutes.

Table 5 *The items in the two versions of the vocabulary tests*

	GS	AW	TECH	SUP	Pseudo	Sum
Version 1	53	20	26	21	60	180
Version 2	54	19	26	21	60	180
Sum	107	39	52	42	120	360

Note.GS= general service; AW= academic words; TECH= technical; SUP=supplementary

Because of the near equivalence of the two versions, correlation between the two versions was relatively high, with a Spearman's rank correlation coefficient of .83. A split-half reliability measure was also performed to measure the internal consistency of the two versions of the vocabulary test. The coefficient was over 0.96 implying that the test items were designed to measure the same psychological characteristics.

Participants

The focus of the present study was on the performance of the 257 engineering majors who completed both versions of the vocabulary test. The number of the pseudo-words checked off was an indicator of candidates who were not responsible for their answers. On average, the percentage of pseudo-words checked off in the present study was under 0.06 (7 were checked off out of the120 pseudo-words). The figure 0.06 was two percent lower than that in Ward’s (2009b) study (5 out of 60), which indicated that the students in this study were serious about the tests. Furthermore, in order to make the findings precise, anyone with more than 7 pseudo-words checked off was eliminated from the data pool. This elimination gave the researchers more faith in the validity of the data because it came from students who were prudent in writing the tests. As a result, results from 124 test takers were considered valid (73 freshmen and 51 sophomore students in the School of Engineering).

Data Analysis

The vocabulary test included two different kinds of items: real words (W) and pseudo-words (P). In such test, the test takers were told to check off the words that they know. Hence, there were two response possibilities for each item: words checked off (Y) or words not checked off (N). The checking off of real words (Y/W) and the rejection of pseudo words (N/P) were both correct responses; while, missing real words (N/W) and checking off pseudo (Y/P) words are false responses.

In fact, the missing of real words was slightly problematic (N/W). When there was no response, it is not easy to detect whether the respondents incautiously miss the real words or if they do not know its meaning. In spite of this, it was assumed in the current study that the missed real words indicated lack of vocabulary because the teachers who helped administer the test confirmed the cooperation and carefulness of the respondents. In this case, the explanatory power of the test depended heavily on the items checked off (Y/W and Y/P), as either Hit (checking off real words or Y/W) or False Alarms (checking off pseudo words or Y/W).

The estimation of respondents' vocabulary sizes was computed using the Correction for Guessing (*cfg*) formula discussed in Machida and Harrington (2006, p.86). The formula is written as follows:

$$\text{Correction for Guessing } (cfg) = \frac{(h) - (f)}{1-(f)}$$

Where *h* represents the observed hit rate, and *f* stands for the pseudo-words checked off rate. The observed hit rate is the number of hits divided by the number of real words (240); the pseudo-words checked off rate is found by dividing the number of checked off pseudo-words into the number of pseudo words (120). For instance, Student A in the present study checked off 3 pseudo-words (f=0.025) and 155 hits (h=0.646). The subject's final score is 0.64 in terms of the *cfg* formula. The figure, 0.64, indicates that Student A has acquired 64% of words in the FEW. As a result, Student A's estimated vocabulary size is about 2,406 words, with the *cfg* score multiplied by the total number of words in the FEW (3,759).

RESULTS AND DISCUSSION

The Number of Words Recognized by the Participants

Students' vocabulary test scores were calculated using the Correction for Guessing (*cfg*) formula. The descriptive statistics from the Correction for Guessing (*cfg*) analysis are reported in Table 6. It can be seen in Table 6 that the average mean score is .593, which is equivalent to 2,229 FEW words. The figure (.593) indicates that the majority of students in the present study have acquired approximately 60% of the 3,759 FEW words, leaving about 40% of the FEW to be learned.

Table 6*The results of scores on Correction for Guessing (cfg)*

Year	N	M/SD	Estimated Size	*t/p*
Freshman	73	.560/.117	2105	-3.51/.001***
Sophomore	51	.641/.139	2410	
Average		.593/.132	2229	

Note.*p*<.05; ***p*<.01; ****p*<.001

In addition, an independent sample test was performed to measure the differences between the sophomores and freshmen. The result in Table 6 shows that sophomores (M=.641, SD=.139) recognized significantly more words (2410) from the FEW than the freshmen (2105; M=.560, SD=.117) and the difference was statistically significant (*t*=-3.510, *p*=.001).

Vocabulary Knowledge of Different Word Categories

Students' word knowledge in each of the four word categories is presented in Table 7. On average, the participants were familiar with 80.2% of GS words, 59.5% of AW words, 47.1% of SUP words, and 40.9% of TECH words.

Table 7 *The word knowledge comparisons between years*

Years	GS M/D	AW M/D	SUP M/D	TECH M/D
Freshman	.793 (.118)	.580 (.164)	.446 (.143)	.322 (.123)
Sophomore	.815 (.108)	.617 (.199)	.510 (.180)	.536 (.174)
Average	.802 (.113)	.595(.179)	.471 (.161)	.409 (.179)
t/p	-1.147/.254	-1.164/.247	-2.281/.024 *	-8.067/.000***

Note.

a. **p*<.05; ***p*<.01; ****p*<.001

b. GS = general service; AW = academic words; TECH = technical; SUP = supplementary

When comparing freshmen and sophomores, the results show that the mean differences for the GS (*t*=-1.147, *p*=.254) and the AW (*t*=-1.164, *p*=.247) were not statistically significant. Significant differences, however, were found for the SUP (t=-2.281, p=.024) and TECH (t=-8.067, p=.000). The sophomores on average performed better than the freshmen. A tentative conclusion can be drawn from the above findings indicating that the engineering sophomores had significantly greater knowledge than their freshman counterparts with respect to the knowledge of the TECH and SUP words, but not the knowledge on GS and AW words. Possible reasons could be that both technical and SUP words are more specific and closely connected with the subject content than other categories of words. As indicated earlier, since technical words represent important concepts to the field of study and SUP words are relevant to the development of the concepts (Nation, 1990; Vidal, 2003), they usually receive more attention in specialized courses. With one more year of training in their content courses, sophomores might have gained a larger number of subject-related vocabularies through the content courses offered by their departments.

On the other hand, the gain of GS and AW words did not present significant difference between the two years of students. Possible reasons could be that most GS vocabulary appeared easy to the students since the majority of students have already acquired these words in high school or their Freshman English courses. As for the low recognized rate of the academic words, two factors may contribute to this phenomenon. First, academic words were not usually introduced in either the general English classes or the subject-related content courses so the students were lack of enough exposure to such type of words. Second, academic words usually representing concepts related to scientific philosophy, the meanings behind these words are very general. They are more like function words, showing relationships between ideas. As a result, compared to subject-related words, academic words are easier to be overlooked in language learning and teaching.

CONCLUSIONS

This study aimed to identify the quantity and quality of the required vocabulary for content-area textbooks reading. On average, the participants recognized about 60% of the words on the FEW. With respect to the four categories of words, the results indicated that students' performance was unsatisfactory, except for the GS (80.2%). Furthermore, sophomores demonstrated better knowledge of subject-related vocabulary (TECH and SUP) than freshmen, but did not have significantly better knowledge of non-subject-related vocabulary (GS and AW).The results of this study suggest that engineering majors in Taiwan need to improve their vocabulary knowledge, especially on the academic and subject-related words. Three pedagogical applications are suggested.

First of all, language faculties can offer English-for-Academic-Purposes (EAP) courses as early as possible. For example, instead of a broadly focused English curriculum, an EAP course with a focus on FEW vocabularies can be provided in the first year of college to prepare engineering students for reading content-area English textbooks.

Second, the four vocabulary categories of the FEW provide a useful guide for teachers and engineering students. Language teachers can use the FEW to check students' knowledge of the needed vocabulary. The use of FEW allows language teachers to design vocabulary learning of unknown words. Another benefit of the wordlist is to bring students' attention directly to the needed words so that their vocabulary learning process can be preceded with more efficiency. Specifically, the FEW with its digitalized corpus can help with both vocabulary instruction and learning. Language teachers are usually suggested to offer learners a number of authentic examples, which show how a word is used in different contexts. Since EFW corpus provides authentic examples, the selection of vocabulary and sentence examples is thus based on empirical data rather than designers' intuition. Furthermore, the use of concordances, which is a corpus device that shows the authentic examples of a particular word in the corpus, plays an important role in vocabulary learning. It is widely acknowledged that repeated exposure to the authentic samples may speed up the word learning process and enhance the acquisition of a "sight" vocabulary (Coxhead & Nation, 2001; Ward, 2009a).

Third, word parts should also be introduced to students. It is found that words based on Greek or Latin roots should be analyzed where possible and the meanings of the word parts (affixes) should be related to the meanings of the words. The suffix "*-meter* (=a means of measuring)" and the prefix "*re*- (=be back or again)" are such examples. These two affixes comprise a large number of related words classified in the SUP and TECH, for example *voltmeter, viscometer, parameter, manometer, galvanometer, calorimeter, thermometer, perimeter, ammeter, reactions, reflected, reflections,* and *resonate* in the TECH; and *diameter, retrieve, refraction, recall,* *react, rearrange,* and *rewrite* in the SUP. This introduction of needed words can be done by teachers and it is also a learning strategy that learners can work on their own for more efficient vocabulary acquisition.

To summarize, the FEW created in this study provides clear goals for language learning and teaching. By using the FEW, learners and teachers may be able to identify words which are more important, or words that should be acquired first, such as words with higher frequency on the list. Furthermore, the composed corpus gives teachers and learners access to many authentic language examples. Through well designed corpus activities, engineering students can improve their understanding in the usage and context of the required vocabulary.

LIMITATIONS AND SUGGESTION FOR FURTHER STUDIES

The instrument used in the present study for vocabulary testing was a yes-no vocabulary test. Although previous researchers, such as Meara (1990), Anderson and Freebody (1981), claimed such test is valid, many practitioners are still concerned about such test because students are not required to demonstrate how well they understand the test items. In order to gain a richer resource of information on students' vocabulary knowledge, future researchers may consider using other kinds of vocabulary measures, such as translation or word association as suggested in Nurweni and Read's (1999) study.

Furthermore, the findings of the present study would be more valid if this study further explored the relationship between students' vocabulary knowledge and reading comprehension of content-area textbooks. The exploration may serve to bring two advantages: (1) it would confirm the assumption that insufficient reading comprehension results from insufficient vocabulary, and (2) it would explain how the knowledge of each of the four vocabulary categories affecting students' reading comprehension. In sum, this study is only the beginning of a comprehensive estimate of students' receptive vocabulary knowledge towards their subject area, and it surely brings up a great deal of possibility for future studies.

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Appendix 1. The textbooks used in the FEW Corpus

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Appendix 2. The first 100 words of the FEW

No.	GS	AW	SUP	TECH
1	the	method	equilibrium	function
2	of	maximum	plan	force
3	a	chapter	magnitude	equation
4	is	error	diameter	flow
5	and	obtain	graph	stress
6	in	defined	resultant	energy
7	to	assume	conditions	section
8	for	required	condition	pressure
9	we	negative	written	system
10	are	initial	acid	class
11	be	obtained	due	moment
12	at	region	circuit	equations
13	as	hence	bar	mass
14	by	interval	tank	velocity
15	with	distribution	respectively	constant
16	an	internal	independent	area
17	on	process	cable	axis
18	from	analysis	principal	shear
19	if	integration	rectangular	functions
20	can	minimum	expressed	vector
21	it	file	associated	fluid
22	or	methods	calculations	surface
23	which	location	decimal	element
24	have	occurs	verify	data
25	has	range	battery	beam
26	will	definition	orbitals	volume
27	when	corresponding	software	forces
28	then	occur	sketch	series
29	its	complex	template	positive
30	where	similar	Newton	theorem
31	between	sequence	recall	normal
32	what	computer	differentiable	elements

(continued)

Appendix 2. The first 100 words of the FEW

No.	GS	AW	SUP	TECH
33	than	structure	plot	pipe
34	into	component	hint	diagram
35	about	requires	calculus	free
36	but	derived	triangle	reaction
37	does	estimate	inner	field
38	would	specific	multiple	components
39	may	input	exerted	integral
40	they	indicated	incompressible	formula
41	should	specified	overloaded	linear
42	was	located	digits	matrix
43	over	ratio	graphs	load
44	your	theory	plastic	radius
45	out	indicates	negligible	current
46	up	assumed	disk	vertical
47	were	compute	calculation	strain
48	us	indicate	lens	potential
49	under	distributed	meters	weight
50	whether	design	mirror	variables
51	off	procedure	default	sum
52	below	approximate	diagonal	variable
53	whose	finite	nonzero	law
54	might	appropriate	programmer	shaft
55	while	available	inequality	particle
56	itself	consists	orbital	parallel
57	onto	source	mathematical	acceleration
58	who	principle	unknowns	derivative
59	yet	approximation	cord	fixed
60	whenever	significant	rotate	string
61	don't	external	triangular	operator
62	yourself	approach	characteristic	power
63	our	require	squares	model
64	within	final	exerts	heat

(continued)

Appendix 2. The first 100 words of the FEW

No.	GS	AW	SUP	TECH
65	been	image	web	vectors
66	that	create	bolt	column
67	this	virtual	stationary	displacement
68	page	rational	intermediate	differential
69	determine	illustrated	clockwise	inertia
70	not	physical	digit	charge
71	two	assuming	matter	flows
72	each	evaluate	stagnation	array
73	point	define	execution	friction
74	figure	contact	profile	boundary
75	example	accuracy	rectangle	coordinate
76	these	previous	aqueous	coefficient
77	value	valid	calculator	molecules
78	one	expansion	completely	electron
79	solution	similarly	meters	density
80	shown	arbitrary	planes	reactions
81	use	portion	rotating	polynomial
82	so	specify	curved	solid
83	line	accurate	elevation	square
84	using	substituting	downward	spring
85	all	approaches	interior	units
86	used	fundamental	twice	atoms
87	number	locate	concrete	rod
88	find	proportional	triple	wave
89	values	text	interpolating	space
90	first	involves	magnitudes	uniform
91	given	finally	shaded	output
92	only	approximately	subscript	loading
93	also	bond	conservation	slope
94	since	computed	duct	dimensional
95	because	preceding	video	algorithm
96	same	instance	cancel	cylinder
97	you	structures	longitudinal	systems
98	see	version	ballon	coordinates
99	time	access	composite	perpendicular
100	must	random	vapor	sectional

(continued)

Note.
a. GS = general service; AW = academic words; TECH = technical; SUP = Supplementary
b. The words are listed according to their frequency. High frequency words appear first.
c. The total number of the words in the FEW wordlist is 3759. Available upon request.

Appendix 3. The yes/no vocabulary test (Version1)

<table>
<tr><td colspan="4">第一大題：個人基本資料</td></tr>
<tr><td>姓名：</td><td></td><td>學號：</td><td></td></tr>
<tr><td>科系：</td><td></td><td>大一英文班別：</td><td>A□ B□ C□</td></tr>
<tr><td>目前年級：</td><td></td><td>性別：</td><td>M □ F□</td></tr>
<tr><td colspan="4">第二大題：測驗說明及範例</td></tr>
<tr><td>測驗目的：</td><td colspan="3">為了解各位學員對於專業英語單字的了解程度；
測驗研究結果,將作為日後您學習專業英語課程設計的依據。</td></tr>
<tr><td>測驗內容說明：</td><td colspan="3">試題中共有 180 個單字，包含真字(real word)和非字(pseudo-word)，真字的部分，是從工學院常用教科書中選取出來的，請誠實地從中勾選出您認識的單字。
p.s.「認識」=能辨認字型 (form)及其字義(meaning)。</td></tr>
<tr><td>作答時間：</td><td colspan="3">共 15 分鐘</td></tr>
<tr><td rowspan="2">測驗步驟：</td><td colspan="3">如果您認識這個單字，也知道它確切的語意(meaning)，請在 Tick 的欄位打勾✓；但若只認得字形，不確定其字義，請不要打勾。</td></tr>
<tr><td>範例:</td><td colspan="2">apple 指的是蘋果(a hard round fruit that has red, light green, or yellow skin and is white inside.)
若您知道 apple 的語意,請在後方 tick 欄位中打✓。
而“Goot” 為非字(pseudo-word)，英文中並無此用字，所以請勿打勾。</td></tr>
<tr><td>評分方式：</td><td colspan="3">真字的部分，每題一分；若勾選到 pseudo-word，則整體分數將大受影響，所以請勾選您確切知道語意的單字。</td></tr>
<tr><td>範例如下:</td><td colspan="3"></td></tr>
</table>

No.	words	Tick	No.	words	Tick	No.	words	Tick
1	apple	✓	36	go	✓	71	ideal	✓
2	collate		37	goot		72	eat	✓

(continued)

請作答

No.	words	Tick	No.	words	Tick	No.	words	Tick
1	function		36	vertually		71	woodle	
2	determine		37	roat		72	entries	
3	sactional		38	vannal		73	flange	
4	floum		39	operation		74	hypothesis	
5	direction		40	ecsent		75	previsid	
6	vector		41	accuracy		76	produsion	
7	work		42	smuth		77	tables	
8	shafter		43	exist		78	exceptions	
9	write		44	linearly		79	generator	
10	variables		45	polynomials		80	segon	
11	exercise		46	setting		81	tatianard	
12	acid		47	drog		82	satisfied	
13	tode		48	commonly		83	membrane	
14	support		49	prome		84	maintain	
15	reactions		50	strains		85	trial	
16	apply		51	capacity		86	maffin	
17	increase		52	muttle		87	invoked	
18	ratio		53	few		88	prevent	
19	inertia		54	stationary		89	tangential	
20	complert		55	curved		90	rates	
21	engineering		56	flowing		91	cut	
22	strant		57	compression		92	knatwork	
23	template		58	rafflers		93	singular	
24	image		59	rows		94	whole	
25	pladed		60	thourt		95	brusses	
26	durein		61	designed		96	proves	
27	origin		62	instant		97	spheres	
28	causes		63	bit		98	plade	
29	estimate		64	lummer		99	piscle	
30	tansion		65	amplitude		100	brittle	

(continued)

No.	Words	Tick	No.	Words	Tick	No.	Words	Tick
31	include		66	held		101	growth	
32	iona		67	intervals		102	syntax	
33	physical		68	bonds		103	physicist	
34	integers		69	refrected		104	restricted	
35	repeat		70	figures		105	slip	
106	slover		141	dumn		176	batony	
107	sertent		142	asselerante		177	colevary	
108	imaginary		143	lose		178	mulerian	
109	parabola		144	simplifying		179	factorial	
110	distructance		145	isothemical		180	manufacture	
111	ordents		146	maxime				
112	release		147	comcrude				
113	strip		148	grow				
114	transformations		149	inelastic				
115	nitorme		150	mutually				
116	ship		151	perimeter				
117	declarations		152	glay				
118	meletrode		153	breaks				
119	executing		154	contributes				
120	ability		155	corrosion				
121	expand		156	incompendate				
122	infanse		157	remark				
123	attraction		158	tendency				
124	fracture		159	boum				
125	conals		160	developing				
126	radians		161	emission				
127	sent		162	ocean				
128	implasit		163	shared				
129	intrasect		164	specifying				
130	scheme		165	accard				
131	viewed		166	narral				
132	assigning		167	discharges				

(continued)

No.	Words	Tick	No.	Words	Tick	No.	Words	Tick
133	campatile		168	efficient				
134	relativity		169	electricity				
135	sequential		170	mathematically				
136	compressor		171	yields				
137	hulps		172	stimulated				
138	saw		173	telephone				
139	tanks		174	zinc				
140	turbulence		175	accommodate				

臺灣工科學生應具備之
教科書基本英文單字研究

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研究指出，工學院學生認為字彙量不足是閱讀原文教科書時最大的障礙，而原文書又是大學求學階段最主要的閱讀教材，若無法掌握書中內容，將有礙專業能力的發展。因此，本研究欲(1)找出工學院學生在閱讀原文書時，必須要認識的單字，並建立一份工學院原文教科書常用字彙表；(2)瞭解工學院大一大二學生對此字彙表中不同類別字彙（一般、學術、專業、補充）習得之情形。藉此我們可以知道學生所具備的單字量，並針對不足的部分施予必要的協助。結果顯示：整體而言學生對於字表的認知達到 60%；對於各類型單字的認知為 80% 一般、60%學術、47%補充、以及 40%專業；大二學生的字彙認知多於大一，主要在於專業和補充單字的表現上，而不是一般以及學術字彙。

關鍵詞：學術英語、教科書、單字表、字彙知識、工程主修

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