The Ability of Taiwanese High-achieving University Freshmen to Comprehend Fundamental English Science Vocabulary

Abstract

The study investigated the extent of knowledge of fundamental English science vocabulary of a group of high-achieving Taiwanese university students. The participants, 35 medical school freshmen, took three 50-science words tests developed by using the words and concepts appearing in the science and health textbooks for American third-grade, fourth-grade, and fifth-grade pupils. The respective grade mean, computed from the total words known × 2 points, was determined to contain as follows: Grade 3 = 43.14, Grade 4 = 24.68, and Grade 5 = 23.60. Despite the sample group representing academic high-achievers, the results showed that most of the participants do not know the English science words beyond the third-grade level. The findings reveal that preparing Taiwanese high school graduates for reading to learn from university texts in English is not a focal concern in EFL instruction. The study suggests that English for Specific Purposes or ESP should be treasured as one of the potential solutions to maximize Taiwanese students' ability to read science texts in English.

Keywords: ESP; Science Vocabulary; Science Reading; EFL

Introduction

The demands of keeping up with the dynamic pace of globalization have led Taiwanese academe to adopt the practice of requiring their students to study scholarly works in English. Yet, before attending university, Taiwanese children are prepared for learning from subject area texts entirely in Mandarin Chinese. As instruction in English represents only a small fraction of the different varieties of courses at Taiwanese grade schools, the effectiveness of the increasingly popular practice of teaching university courses entirely in English requires some form of validation.

This study is part of a series of research designs to examine reading ability of Taiwanese university students in English, in light of a general goal of delineating their problems and difficulties in learning from discipline specific texts in English. In this paper we firstly present the context of the issue, followed by a review of the relevant research, and finally the study. The study may be of interest to professionals in ESP or countries where students are facing the need to learn a new language while simultaneously being required to comprehend texts in that language in order to succeed academically, and where teachers are often bilingual and using texts written in their second or foreign language.

The Context

The academic world of Mainland China and Taiwan as well as other Asian nations has favored the practice of studying scholarly works and publishing papers in internationally refereed journals in English (Li, 2002). Passing the test of English as a Foreign Language (TOEFL) or other English proficiency tests has also become a part of the basic requirements for graduation from Taiwanese universities. Paradoxically, placing such a high value on English in higher education has not successfully led to learners' competence in the English language. According to Gluck (2007) writing in

the BBC News, Taiwan ranked 17th in 2006 among the top 20 Asian countries which had the highest number of people taking the International English Language Testing System (IELTS). Subsequently, Hu (2008) reported in the Taiwanese Liberty Times that Taiwan ranked last among Korea, Hong Kong and Singapore in the Test of English as a Foreign Language (TOEFL-iBT) administered in 2007.

There have been moves over the past five years among universities in Taiwan proposing to teach content courses entirely in English as evidence of campus globalization and academic excellence" (Chen, Hu & Liu, 2008; Hu, Chen & Liu, 2008). Many universities, regardless of ranking, are eager to adopt this policy. In the fall of 2008, some top-ranked universities, such as National Taiwan University, announced that the courses instructed entirely in English had reached 10%. Yet, experts in TEFL have disclosed that it is common to hear teachers and students communicate in awkward English in which the English sentences are fraught with Chinese syntax (Cheng, 2010; Hu, Chen & Liu, 2008). The students' responses, on the other hand, vary significantly as well: some favor the courses as they believe it is a way to improve English, whereas others expressed frustration because they could not understand the English used in these courses (Chen, Hu, & Liu, 2008; Cheng, 2010; Hu, Chen & Liu, 2008). As Cummins and Man (2007, p. 801, cited in Lessard-Clouston, 2009) point out, "as academic language proficiency includes knowledge of the less frequent vocabulary of English as well as the ability to interpret and produce increasingly complex written and oral language, acquiring academic language is challenging for all students." The effectiveness of learning from the university discipline-specific texts in English in the Taiwanese EFL context remains inconclusive and awaits intensive empirical research.

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Observations of how Taiwanese university students read discipline-specific texts in English have indicated that much of their reading time has been taken by checking words in the dictionary and recording their Chinese equivalents (Cheng, 1993). Further research on English reading difficulties encountered by the doctoral and graduate students at public universities in Taiwan found more data. A large percentage of the subjects of the study, 87 to 88%, experienced great comprehension difficulty with both the English lexis and syntax of the scholarly works that they were attempting to read (Yiau, 1993). Cheng (2010) used the Gates-MacGinitie Reading Tests to evaluate Taiwanese university students' reading grade equivalents. In the study, Cheng administered the Fourth Edition, Level 7/9, Form S of the GMRT to two groups of university freshmen in Taiwan, each representing the upper 1.76% and approximately the upper 25% among the Taiwanese university freshmen majoring in sciences and engineering, respectively. The results indicated that 77.67% of the 94 participants in the upper 1.76% group scored below Grade 10 and 82.35% of the 153 participants in the next upper 25% group scored below Grade 7.

As Thompson (2003) states, in understanding the lectures typical of English-medium university studies, ESL as well as EFL students face numerous challenges, including learning general academic vocabulary (Nurweni & Read, 1999) and mastering the specialized or technical vocabulary of their academic disciplines (Coxhead & Nation, 2001; Lessard-Clouston, 2006, 2008, 2009). All fields draw on a specialized lexis (Hyland & Tse, 2007). As vocabulary appears to be the basic aspect in understanding a text, EFL/ESL students preparing for university level studies need adequate vocabulary if they are to understand their course textbooks (Konstantakis, 2007). Accordingly, this study advocates testing of Taiwanese university students to measure their knowledge of basic English science terms and concepts. The results

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would give insight into the problems that Taiwanese university students encounter when reading discipline-specific textbooks. The results would also offer positive insight for English remedial classes given as prerequisites to more difficult subjects.

Review of the Literature

Research into vocabulary acquisition and use has divided vocabulary into four levels (Coxhead, 2006; Nation, 2001) as follows:

1. General or high frequency
2. Academic vocabulary
3. Technical vocabulary or words for specific purposes
4. Low frequency words

However, Chung and Nation (2003) point out that there has been little agreement over the definition of technical vocabulary and how to count it reliably. To help learners notice and learn technical vocabulary, a four step scale was devised using anatomy as an example to illustrate the classification of words as being technical or non-technical. Table 1 displays the scale adapted from Chung and Nation (2003, p.105).

Table 1: A rating scale for finding technical words (as applied to an anatomy text)

Step 1: Words such as function words that have a meaning that has no particular relationship with the field of anatomy; that is, words independent of the subject matter. Examples are: *the, is, between, it, by, adjacent, common, commonly*.
Step 2: Words that have a meaning that is minimally related to the field of anatomy in that they describe the positions, movements, or features of the body. Examples are: *superior, part, forms, pairs, structures, surrounds,*

supports, associated.
Step 3: Words that have a meaning closely related to the field of anatomy. They refer to parts, structures or functions of the body. The words are also used in general language. The words may have some restrictions of usage depending on the subject field. Examples are: *chest*, *trunk*, *cage*, *cavity*, *organs*, *liver*, *abdominal*.
Step 4: Words that have a meaning specific to the field of anatomy and have clear restrictions of usage depending on the subject field. The words are not likely to be known in general language; they may be also known in other fields but with a technical flavor. Examples are: *thorax*, *sternum*, *vertebrae*, *pectoral*, *fascia*, *trachea*, *mammary*.

Chung and Nation (2003, p.105) add that "words in Step 3 may be technical terms in a specific field like anatomy and yet may occur in other fields and not be technical terms in those fields." They further comment that words like *thorax* and *mammary* in Step 4 may be known in other fields but thought of as being anatomical terms. According to this rating scale, "sound" for example belongs to words in Step 3 and may appear as follows:

1. "the noise made by nature or people" (in physics);
2. "a sea or ocean inlet larger than a bay or a narrow sea channel between two bodies of land" as in Long Island Sound (in geography);
3. "to make noise" (as a verb); and
4. "perfect" or "sturdy" (as an adjective).

There have been various tracks of research into general, academic and technical words. Nurweni and Read (1999) conducted a study on how many words freshmen of an Indonesian university knew. The results showed that the subjects knew only 240

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out of the 800 words in the University Word List's (UWL) (Xue and Nation, 1984). To delineate the general English vocabulary grade equivalents of Taiwanese university students, Cheng (2009) administered the vocabulary subtest of the Gates-MacGinitie Reading Tests (GMRT), Level 7/9 Form S, to 209 freshmen who represented the upper 3.14% among the Taiwanese university freshmen majoring in sciences and engineering. The results showed the following grade distribution by percentage: Grade 4 - 3.35%, Grade 5 - 15.31%, Grade 6 - 31.11%, Grade 7 - 22.96%, Grade 8 - 20.09%, Grade 9 - 4.30%, Grade 10 -1.44%, Grade 11 - 0.48%, Grade 12 - 0.48%, and Grade PHS (post high school) - 0.48%.

West (1953) developed a General Service List (GSL) which contains 2,000 headwords chosen mainly on the basis of frequency. Coxhead (2000) devised an Academic Word List (AWL) of 570 headwords from the Academic Corpus of 3.5 million words which consisted of textbooks in Art, Commerce, Law and Science. Nation (2004) reduced West's 2,000 headwords to 1,986 after conducting a validation study to ascertain the validity of the GSL and the AWL. Thus, headwords from both lists make up a total of 2,556 word families. The two lists comprise 86.1% when tested on the whole Academic Corpus (Coxhead, 2000).

Nation (2004) also reported his findings when testing the GSL and the AWL on four other corpora. The two lists combined provided coverage of 85.5% to 91.4%. In science based written academic English, Coxhead and Hirsh (2007) reported coverage of 80% over a corpus of approximately 875,000 words. They conducted further corpus-based studies of the vocabulary in academic science textbooks to establish whether there is a science-specific vocabulary containing words outside of these two major lists. They found 318 such word families covering 4% of a science-specific corpus of 1.5 million words.

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Fry (1993) listed from American school subject area textbooks the technical terms he believed basic and essential to the study of life science, physical science, geometry, mathematics, social studies and geography. The life science word list for grades four through nine encompasses 226 terms such as *dendrite*, *reflex* and *skeletal muscle*. The physical science vocabulary list is made up of 231 terms for grades four through high school. Examples are *absolute zero*, *diode* and *hologram*. The geometry list for grades three through nine consists of 163 terms. Examples include *acute triangle*, *coordinate plane* and *tangent*. In mathematics, Fry listed 150 terms such as *decimal*, *equation* and *median* for primary grades and 221 terms like *binary operation*, *natural number* and *sine* for grades four through eight. The social studies word list contains 165 terms such as *peasant*, *slum* and *union* for grades three through five; while for secondary grades the list includes 296 terms with *legislature branch*, *poll tax* and *public domain* as some of the examples. *Contour*, *fiord* and *flood plain* are the examples among 284 terms listed from middle grade geography textbooks. The problem of Fry's word lists is that each list covers many grades at a time; for instance, the life science list covers grades four through nine. With the words alphabetized, it is very difficult for the readers to see which words are appropriate for lower grade levels.

There has been some research into the effects of listening on technical vocabulary learning. In France, Kelly (1991) documented that the main obstacle to advanced EFL learners' listening comprehension in a science faculty was "lexical ignorance." Lexical problems account for almost half of all errors, while perceptual ones represented 38.5% and syntactical ones just 13%. In Spain, Vidal (2003) found that listening to videotaped tourism lectures produced a significant gain in the vocabulary learning of her first-year university ESP students. Vidal's study showed

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that students' test performance was much better with technical vocabulary than with low-frequency and general academic terms.

Some research has investigated university professors' use of definitions of various types of words in science (Flowerdew, 1992; Jackson & Bilton 1994). Flowerdew (1992) examined all of the definitions in eight teachers' randomly selected videotaped lectures for EFL students in science classes. The study documented 315 definitions in about 605 minutes of lectures, with on average 20 per lecture. The results revealed that definitions were common but there was considerable variation. The characteristics of definitions are likely to vary according to subject matter and audience. In another study dealing with vocabulary in geology lectures in an Omani university, Jackson and Bilton (1994) investigated "elaboration", or the use of a base word or phrase followed by one or more different ways of expressing it. The results revealed that on average the frequency of vocabulary elaboration was about one per minute. The elaborations dealt mostly with technical (55.8%) or semi-technical (10.6%) terms, and half of the elaborations they found were some form of definition. The lecturers often wrote on the board or referred to lecture handouts as they gave specific elaboration, most often their vocabulary explanations were not highlighted phonologically or verbally. Yet, in a case study investigating if professors' use of definitions varied between science and theology, Lessard-Clouston (2009) found that several different types and categories of definitions were used in the theology lectures he attended, and "it was not unusual for there to be some written or visual support – in lecture outlines, on handouts, on the class white board – for these terms or phases as they were being defined orally" (p.16).

For ESL/EFL university students in a range of disciplines, general academic and technical vocabulary is crucial to their understanding of and socialization into their

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domains (Lessard-Clouston, 2009). In native English settings, professionals also highly value the comprehension of scientific and technical terms regarding a student's ability to read and learn from texts. Singer and Donlan (1989) state that the general English reading books do not as a rule contain scientific and technical terms. A student may have good general reading skills, but still have difficulty in reading materials in a specific field of study. The common type of specialized words with technical meanings and abstract concepts often appear in science textbooks in physics, chemistry, astronomy, technology, health and biology. These are quite diverse, if sometimes overlapping, fields. Each has its own special lexis and concepts (Dechant & Smith, 1961, Singer & Donlan, 1989). Such scientific or specialized vocabulary has to be taught (Coxhead, 2006; Nation, 2008; Singer & Donlan, 1989).

As the review has revealed, however, there has been no research to date on the comprehension and knowledge of basic science technical terms in the ESL as well as the EFL contexts. The existing data have documented that EFL university students are deficient in both general and academic words (Cheng, 2009; Nurweni & Read, 1999). Despite the fact that university professors often use definitions to clarify various types of words in lectures (Flowerdew, 1992; Jackson & Bilton 1994; Lessard-Clouston, 2009), no research documents whether or not professors have a clear picture of their ESL/EFL students' knowledge of basic technical terms. With the lack of this knowledge, coupled with ESL/EFL students' poor command of general and academic words, university professors might not adequately present what their students actually need while lecturing. In addition, poor command of general and academic words decreases an ESL/EFL student's comprehension of the lectures even if the professors define the technical terms contained in their lectures. Given these circumstances, this study devised an approach, utilizing a group of Taiwanese EFL university students, to

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explore the following question: Using the grade levels in the American school system as indicators, at which grades are Taiwanese high school graduates most likely or unlikely to comprehend scientific terms in English?

By using science terms as a measuring rod, the author of this study subscribes to the rationale that grade level words provide insight into what students read and comprehend. As other researchers have established, grasp of lexical meanings are the strongest factor in reading comprehension (Chall & Stahl, 1985). Word meaning scores are so highly correlated with reading comprehension scores that a reading vocabulary test may be substituted for a paragraph meaning test (Chall, 1987).

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Methodology

The study employed the concept of grade equivalents (GE). Grade equivalents are based on the average scores earned by students in each of a series of grades and are expressed in years and months (Lipson & Wixson, 1991). They are often found in norm-referenced group survey tests such as: Gates-MacGinitie Reading Tests (GMRT) (MacGinitie, MacGinitie, Maria, & Dreyer, 2002); criterion-referenced tests (Slossen, 1988); and Informal Reading Inventory (IRI) (Burns & Roe, 1989). For instance, in an IRI, a representative passage (200 to 500 words, depending on grade level) is selected to represent each of the grade levels from primary to 12th grade. After administering the test, the IRI criterion is then checked to match the grade with the test taker's three levels of reading ability: independent, instructional and frustration level (Burns & Roe, 1989).

Definition of Terms

In this study, the "fundamental science vocabulary" was defined as those "science words and concepts" the students in English as a native tongue setting have learned or acquired at elementary school. The science vocabulary may contain

concepts which may consist of one or more than one lexical item. In this study, the "fundamental science vocabulary" was selected from the words and concepts that are alphabetized in the Glossary of the graded series of science and health textbooks for American pupils at Grades 3, 4 and 5.

The science vocabulary was selected from *Discover the Wonder*, an elementary school science textbook series published by Scott, Foresmen and Company in 1993. The third-grade textbook consists of six topics on Habitats, Gardening, Finding Shelter, Moving, Sounds All Around, and Protecting the Earth. The fourth-grade and the fifth-grade textbooks contain the same topics on Taking a Closer Look, Pedaling Uphill, Fun in Motion, Running on Sunlight, Electricity, and Living off the Land. The following is an example of the text (the highlighted words appear in the Glossary):

> "Water that becomes a gas is called **water vapor**. Water vapor disappears into the air. You can't see it or touch it. Some water vapor stay near the ground and some move high into the air." (Grade 3, p. A34)

The health vocabulary was chosen from *Health for Life*, a series also published by Scott, Foresmen and Company in 1987. Across the three grades, the textbooks deal with the same topics on Understanding Yourself, Your Body, Physical Fitness, Knowing How to Be Safe, Foods and Your Body, Medicines and Other Drugs, Preventing Diseases, and Working for a Healthy Community. An example of the text is as follows (the highlighted words appear in the Glossary):

> "When you breathe in, air goes from your nose to your throat and down your windpipe, or **trachea**. This tube splits into two large branches, **the bronchial tubes**. One branch goes into each lung…" (Grade 5, p. 90)

In the data analysis, "knowing the words" or "words known" refers to "the English science words comprehended by the participants." According to Miller

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(1999) and Richards (1985), "Knowing a word" may involve several skills, e.g. ability to define it, the ability to recognize situations for using it, knowledge of its alternative meanings, and the ability to recognize inappropriate uses of the word. In this study, however, "knowing a word" refers to "the recognition of word form and meaning."

Participants

The study involved 35 medical school freshmen selected from the Department of Medicine of a prestigious medical university in Taiwan. The department is among the top 11 university departments in Taiwan; it only accepts the top 1.00% of the high school graduates and provides seven-year training leading to the Bachelor of Medicine degree. The participants' proficiency in English was determined by the scores on the English segment of Taiwan's National College Entrance Examination held annually in July. The results of the English test were weighted on a scale of zero to 100. The English scores of the participants averaged 87.60 (N=35, Range=80~97, SD=4.995). As the English test is written by commissioned college professors about ten days before the examination is held, no reliability or validity data of such tests have been established. The national mean of the English examination fluctuates from year to year. Table 2, therefore, intends to give an indication of how these participants compare with their peers in reading ability in English (CEEC, 2009).

Table 2: National English Mean of Taiwan's National College Entrance Examination

	Examinees	Mean	Mean of Top 1/3 Examinees
2003	119,785	39.9	69
2004	111,494	31.2	55
2005	108,116	37.0	65

2006	104,505	33.9	63
2007	95,106	31.1	57
2008	93,681	42.6	73

As large-scale studies are impossible at present, the study uses only high-achieving students. The results are intended to help estimate how much knowledge of basic English science vocabulary most Taiwanese university freshmen currently demonstrate to serve as a form of baseline study for future studies that may involve larger groups of participants or groups with lower proficiency scores. In exercise of ethical standards, the participants were told about the purposes of the tests. Thus, at the beginning, 43 students participated; near the end, 8 students expressed their unwillingness to continue.

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Grade Selection

In selecting the starting and the ending grades, the researcher made five copies of the glossary from Grades 1 to 6 texts in Science and Health. Five freshmen from the original 43 students were invited to judge the level of difficulties of each copy over a two-week period. The raters unanimously reported that Grade 1 and Grade 2 were easy for them; while Grade 6 was considered quite difficult. Ratings on Grade 3, Grade 4 and Grade 5 ranged from difficult to not difficult. The words appearing in Grade 3, Grade 4, and Grade 5 were then selected for this study.

Instruments

Based on the four step rating scale adapted from Chung and Nation (2003), the words among the glossaries consist of both Steps 3 and 4 words. Moreover, the glossaries contain some acronyms. To avoid confusing the participants when answering the tests, the researcher worked with two university English teachers to either retain or remove some acronyms and Step 3 words. The following steps were

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taken:

1. Acronyms: In the graded textbooks, *EPA*, *DNA*, *CFC*, *DDT*, *HDTV*, *NASA*, and *PFD* were the acronyms; however, only *DDT*, *DNA* and *NASA* were retained as they were more common in popular science repertoires.
2. Words whose technical and non-technical meanings are equally salient and could be known instantly were removed. Examples are: *power* and *force*.
3. Words whose technical meanings are more often stressed than non-technical meanings in Taiwanese EFL classrooms were retained. Examples include *gravity* (associated with Newtonian physics) and *marrow* (associated with bones). Also retained were words whose non-technical meanings are more frequently taught in Taiwanese EFL classrooms, but whose technical meanings are believed to offer an insight into how extensively the students read science in English. One example is *crown*. To make the words specific, the researcher included under each word in the booklets one of the terms in Mandarin: health, earth science, and physics.
4. In the graded textbooks, the words that appear in a lower grade textbook commonly reappear in higher grade texts. The repetition provides a clue that the word is technical (Chung & Nation, 2003). The researcher then categorized the word in the grade in which it is first used. The words in the different grade levels of Science and Health tally as follows: 1) Science: Grade 3, 80 words; Grade 4, 105 words; and Grade 5, 155 words; and 2) Health: Grade 3, 24 words; Grade 4, 41 words; and Grade 5, 43 words.
5. The researcher then combined Science and Health under the category: Science. The total number of words from the three grade levels is 448; with 104 words at Grade 3, 146 words at Grade 4 and 198 words at Grade 5. To avoid discouraging the participants due to exhaustion from taking long tests,

it was decided that 50 words be randomly picked out of each grade. The 150 words make up 33.48% of the pool, with 48.08% at Grade 3, 34.25% at Grade 4 and 25.25% at Grade 5.

6. While interacting with a group of Taiwanese seventh grade students in their Biology class, the researcher found that most could interpret the Mandarin biology terms without context clues. For example, the students interpreted freely when asked to interpret these unrelated Mandarin biology words: *xylem*, *ventricle*, *marrow*, *hemoglobin*, *chlorophyll*, *chromosome*, *amphibian*, *mammal*, *membrane* and *budding*. Due to their positive participation, context clues were not provided for each of the science lexical items in this study. The test booklet for each grade was an A4 sheet of paper with 50 words typed in two columns. Students were directed to answer each word by providing its Mandarin equivalent or interpreting the word in either English or Mandarin. Each correct answer was awarded 2 points.

Procedure

The tests were administered in a regular freshman English class over three consecutive weeks in the first month after the participants entered university. In a period of 50 minutes, the participants responded to the words in each grade over the three weeks. Students were encouraged to try their best to provide answers in Mandarin or interpret in either Mandarin or English.

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Grading

Two university English teachers were invited to grade the measures in a three-week period. The answer keys consisted of two versions: answers in English which was a direct copy from the definition in the Glossary and Mandarin equivalents in traditional Chinese characters in which acceptable variations in the answer were

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also given to guide the raters. For example, the answer key to *gravity* consisted of five expressions: *zhong li*, *yin li*, *dixin yin li*, *wan you yin li* and *dixin xili*. Another example is *endangered*, which means *kuai yao jue zhong de*, *kuai yao mei zhong de* and *bin lin jue zhong de*, and *jiang yiao jue zhong de.* As there are many homonym characters in Mandarin, miswritten characters and misused homonyms were counted correct if they did not influence the raters' comprehension.

Take *endangered* as an example of wrong or correct response; some participants answered it without either the character *de* or *yao*. Since it did not interfere with the comprehension of the raters, the response was counted correct. However, a couple of participants answered it as *bei wei ji de* or *bei wei hai de*, which means "to jeopardize, to hurt, or to bring into danger." Responses such as those were counted incorrect. In the third week, the researcher held discussion sessions focusing on discrepancies in grading.

Data Analysis

The SPSS for Windows Release 11.5.0 (SPSS, 2002) was used to organize and analyze the data collected in the study. As the study used only one group of students and three tests of different contents and difficulty were administered, three paired samples *t* tests were conducted to examine whether there were significant differences in the performances of the measures from Grade 3 to Grade 5. Next reported were the rank-ordered percentages of the performances. These percentages provided a general picture of the subjects' ability to comprehend basic words in science. Finally, correlation coefficients were computed to test whether the participants' effort deployed in completing the measures were random or consistent.

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Results

Statistic Computations among Test Results across Grades

In this study, 2 points were awarded to each word known. Table 3 reports the descriptive statistics of the performances at Grades 3, 4 and 5. The mean is 43.14 at Grade 3; however, it plunges to 24.68 at Grade 4 and to 23.60 at Grade 5.

Table 3: Descriptive Statistics: Words Known × 2

	Mean	N	Min.	Max.	Std. Deviation
Grade 3	43.14	35	30	66	8.93
Grade 4	24.68	35	10	52	9.73
Grade 5	23.60	35	10	42	8.70

To put forward possible significant differences in the performances at different grade levels, three paired samples *t* tests were conducted. Significant differences were found in the performances on the measures at Grades 3, 4 and 5, with a significant difference between Grade 3 and Grade 4, $t(34) = 17.16$, $p = 0.000$, and a significant difference between Grade 3 and Grade 5, $t(34) = 20.28$, $p = 0.000$. No difference, however, was observed between Grade 4 and Grade 5, $t(34) = 0.88$, $p = 0.381$. The results indicate that the participants performed significantly better on the test at Grade 3 than they did at Grade 4 and Grade 5. Table 4 displays the results.

Table 4: Paired Samples *t*-Tests for Science Terms

		Mean	Std. Deviation	*t*	*df*	Sig.
Pair 1	G3 - G4	18.45	6.36	17.16	34	.000
Pair 2	G3 - G5	19.54	5.70	20.28	34	.000
Pair 3	G4 - G5	1.08	7.23	0.88	34	.381

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Percentage of Words Known

Students' performances on the individual words are reported by the accumulated percentage of each word known. This formula was employed to tally the percentage: number of participants who knew the word correctly divided by the total number of participants. Under this formula, a percentage of 100% indicates that all participants know the individual word; while, a percentage of 0.0% signifies that none of the participants knew the word. Table 5 displays the science words all participants know (or 100%) by grade. At Grade 3, for instance, all participants comprehend 11 words or 22%; however, this number decreases to 4 words or 8% at both Grade 4 and Grade 5.

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Table 5: Science Words All Participants Know × Grade

Grade	Words All Participants Know
Grade 3	bacteria, blood vessel, calcium, membrane, photosynthesis, protein, seed coat, side effect, tissue (health), virus, volume (physics)
Grade 4	ecosystem, gravity, Homo sapiens, molecule
Grade 5	atomic number, chemical bond, enzyme, organelle

As a contrast, Table 6 displays the lowest percent, zero percent, which is also an indication of a word that none of the participants knows. For example, at Grade 3, the entire cohort of participants does not know 8 words or 16%. This number, however, increases to 12 words or 24% at Grade 4, and to 15 words or 30% at Grade 5. The percentages of the rest of the science words the participants know are listed in Appendix A.

Table 6: Science words No Participants Know × Grade

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Grade	Words No Participants Knew
Grade 3	bran, convection, crown (health), enamel, humus, loam, pasteurize, sleet

Grade 4	anemometer, bicuspid, capillary, lithosphere, mantle (earth science), molar, orthodontist, plankton, scurvy, seismograph, solstice, weathering
Grade 5	astigmatism, bronchial tubes, dendrite, diaphragm, emphysema, esophagus, geode, hydroponics, inertia, iris (health), legume, pituitary gland, pyrethrum, stamen, ventricle

Correlations among Test Results across Grades

Pearson *r* was employed to compute the correlation coefficients among the test results among grades. The results show significant correlations among the performances on the tests across Grades 3, 4, and 5, with a correlation of $r = 0.771$ between Grades 3 and 4, an r of 0.791 between Grades 3 and 5, and an r of 0.698 between Grades 4 and 5. The results suggest that the performances of the participants on the measures are consistent. Table 7 displays the data.

Table 7: Paired Samples Correlations

		Grade 3	Grade 4	Grade 5
Grade 3	Pearson *r*	1	.771	.791
	Sig. (2-tailed)	.	.000	.000
Grade 4	Pearson *r*	.771	1	.698
	Sig. (2-tailed)	.000	.	.000
Grade 5	Pearson *r*	.791	.698	1
	Sig. (2-tailed)	.000	.000	.

Discussion

The study endeavors to provide answers to the research question: Using the grade levels in the American school system as an indicator, at which grades are Taiwanese high school graduates most likely or unlikely to comprehend the words

and concepts in science written in the English language? In this study, if the mastery level was set at 85% as a criterion-referenced mastery test does (Gronlund, 1982), the percentages of words known by the entire cohort of participants across the three grades are very low: Grade 3, 28%; Grade 4, 12%; and Grade 5, 12%. In addition, the highest score the participants achieved was only 66, at Grade 3. At Grade 4, the highest score was 52 while at Grade 5 it was 42. Similarly, the group means were very low: Grade 3, 43.14; Grade 4, 24.68 and Grade 5, 23.60. Among the 150 science words tested, the entire participant cohort did not know 35 words or 23.33%.

A closer look at the science vocabulary all participants know, words such as: *bacteria*, *blood vessel*, *calcium*, *ecosystem*, *gravity*, *Homo sapiens*, *membrane*, *molecule*, *photosynthesis*, *protein*, *side effect*, *tissue*, *virus*, *volume*, *proton* and *sperm* are likely the words appearing in general English readers introducing science or technologies to EFL students. In addition, through checking the 10th-grade Biology textbook published in 2008 by Han Lin Publishing Co., Ltd., in Taiwan, the researcher found that every key science word in English is placed in brackets following their Mandarin equivalents in the science textbook written in Mandarin. Some examples are *chromosome*, *organelle* and *photosynthesis*. In the middle school science textbooks, however, English equivalents of the Mandarin science terms never appear within the texts or in the appendix. Nevertheless, the researcher observed that in an eighth-grade science class, the teacher introduced and wrote on the board the English equivalents of the Mandarin terms: *density*, *mass* and *volume* which are the key concepts in the chapter. More interestingly, in a seventh-grade biology class, students preferred using the English term *DNA* over its Mandarin equivalent as it contains six characters: *qu yang he tang he suan*. This suggests that at middle and high schools some science teachers may have introduced the English equivalents of

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the key words or concepts in Biology, Chemistry and Physics. Nevertheless, the poor performance scores of the participants in the study indicate that Taiwanese science teachers usually do not introduce the English equivalents of the Mandarin key concepts nor do they draw their students' attention to the English technical words, albeit they are placed in brackets following their Mandarin equivalents in the textbook.

The findings suggest that the participants are deficient in knowledge of basic science words beyond Grade 3. As the subjects represent the top 1.0% of the high school graduates in overall school achievement among Taiwanese youths, the results imply that the majority of Taiwanese university freshmen or high school graduates are seriously deficient in knowledge of basic science words in English beyond Grade 2. The causative factors are diverse; for example, middle school and high school students are not instructed to learn the English technical terms appearing in their texts and high school EFL instructions focus mainly on daily dialogues and humanities. In addition, the instruction of the compulsory high school subjects - Mathematics, Biology, Physics, Chemistry, Mandarin Chinese, History, Geography, Civics and English, uses Mandarin Chinese as the classroom language of instruction. Accumulation of these fundamental science words in the English language in Taiwanese high school teaching context is therefore constricted (Cheng, 2010).

Conclusions

The study reveals that Taiwanese university students are under-prepared to use texts written in the English language. Thus, student insufficiency in general English reading ability (Cheng, 2010) and failure to systematically attend to three essential elements of the educational innovation, namely, teacher (re-)training, curricular content and learning/teaching materials (Rea-Dickins, 1994), the efficacy and quality

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of reading to learn from university texts in the EFL context is questionable. As Mandarin is the dominant language in preparing children for learning from subject area texts before attending university, the avenue of learning through Mandarin texts is treasured as one of the efficient and quality tools.

Implications for ESP Instruction

In Taiwan, most high school and university EFL teachers are trained in either English literature, linguistics or TEFL methodologies which focus on grammar, listening, writing, speaking and reading. Most of them grew up in a non-English environment and have never been educated to read to learn from science, mathematics, health or biology in English. They might not have developed the English vocabulary of the field-specific concepts. They simply do not have the required training for preparing high school graduates for reading to learn from university discipline-specific texts in English.

In light of the limitations in the current EFL educational framework in Taiwan, English for Specific Purposes or ESP which focuses on helping students to learn the specialised English used in a specific discipline and developing the language skills required by professionals in a specific field should be treasured as one of the potential solutions. Many Taiwanese EFL teachers are familiar with the meaning of ESP; nevertheless, very few of them are able to teach and plan such a course because of their lack of training in ESP. As EFL teaching is not satisfactory in Taiwan, what is needed at this moment in Taiwan is how to convince TEFL professionals to go beyond merely teaching the four language skills and to accept ESP as an alternative approach in assisting university students in learning from discipline-specific texts in English. Then more ESP courses should be planned to train teachers how to teach such courses.

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In Taiwan's high schools, English teachers and policy makers may believe that teaching science is the responsibility of science teachers. They may also believe the major mission of an English teacher is to teach students how to read English. It is true that science teachers are not trained to teach their courses in English; they naturally use Mandarin Chinese exclusively as the vehicle of instruction and communication. However, they are supposed to be familiar with the concepts and special English vocabulary in the subjects they are teaching. It is therefore recommended that high school science teachers should inform their students of the English equivalents of the Mandarin science words and concepts appearing in the textbooks. Cooperation should be worked out between science teachers and EFL/ESP teachers for preparing students the basic science words and concepts in English.

Implications for Further Research

In this study, some students know more words than the others. Since the participants were high school graduates from different regions in Taiwan, they may have diverse English learning experiences. The underlying causative factors, such as high school science teachers' attitude towards introducing science words in class, await further research. In addition, studies should also be designed to examine how university students beyond the freshman year learn science words and concepts. In these studies, their learning experience, their growth as well as the approaches they use in learning science words and concepts can be described. The results serve to inform university content teachers of the effective approaches as well as the problems and difficulties of their students in learning science technical words in English.

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As most university subject area teachers in Taiwan are also EFL learners who are very successful in learning the technical words in their specialized fields, it will be very beneficial to conduct studies on them to gather the approaches they have used in

learning the technical words. Together with the effective approaches suggested by Chung and Nation (2003) and Coxhead (2006), university ESP teachers as well as subject teachers can prepare their students for learning technical words in English.

Graded science textbooks across different English-speaking nations should be examined to see if their teaching foci vary from nation to nation. Then like West's General Service List (West, 1953) and Coxhead's Academic Word List (Coxhead, 2000), a more focused list of graded basic and daily science words than Fry's (1993) should be formulated and validated for EFL students.

Finally, given that there exist no standardized or criterion-referenced tests for assessing EFL high school graduates' ability to read university science or social science texts in English or for determining whether learners are properly trained for reading university English science texts, it may be beneficial to develop such tests. The tests used in this study could constitute a good starter kit in such an endeavor.

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刪除: In this study, only one textbook series was used for selecting the graded science terms. To increase the reliability and validity of the measures on the graded science words, in future studies the selection of the words should include three or four of the science textbooks adopted by different American school districts. Studies with a larger group of students and groups with lower proficiency scores should be replicated. . In addition, g

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Appendix A: Percentages of Science Words Known × Grade

Grade	Words Known from 99.9 % to 02.9%
Grade 3	fossil fuel (97.1), carbohydrate, extinct (91.4), endangered (85.7), embryo, exoskeleton (74.3), primary teeth (71.4), condensation, fertilizer, water vapor (57.1), algae, eardrum (54.3), thermometer (51.4), antenna, nicotine, (45.7), vaccine (42.9), conductor (physics) (37.1), cavity (health), small intestine (25.7), vocal cords (22.6), saliva (17.1), incinerate (11.4), hibernate, insulator, tendon (08.6),

	agility, lever, plaque (health) (0.57), germinate, precipitation, tidal wave (02.9)
Grade 4	biosphere (94.3), core (earth science) (85.7), respiratory system (80.0), immunity (77.1), decomposer (71.4), saturated air (62.9), cold front, pulse (health/physics) (54.3), pore (51.4), hydrosphere (42.9), sonic boom (34.3), erosion (31.4), eruption (earth science), pollination (28.6), thrust (physics) (25.7), lava (22.9), cardiovascular, fault (earth science), reef (17.1), cumulus cloud (08.6), epidermis, gum (health), marijuana (08.6), barometer, crust (earth science), mucus (05.7), asteroid, deciduous tree, magma, meteorite, meteorologist, rain gauge, stethoscope, tremor (earth science) (02.9)
Grade 5	chromosome (94.3), kinetic energy (85.7), proton, sperm, velocity (82.6), coordination (45.7), vacuole (42.6), hemoglobin, pancreas (40), hybrid (34.3), spectrum (31.4), marrow (health), quark (28.6), macrophage (22.9), decibel, stroke (health), urinary bladder (17.1), fungicide, pheromone, plasma, tissue culture (11.4), magnetism, ovule, power surge (08.6), cerebrum (05.7), cartilage, gastric juice, hallucinogen, ligament, nodule, trachea (02.9)

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In geography it means "

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As a part of speech, this verb means

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第 6 頁: [37] 刪除	user	2010/11/22 12:12:00 PM

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第 6 頁: [37] 刪除	user	2010/11/22 12:12:00 PM

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The results showed that the subjects knew only 240 out of the 800 words in the University Word List's (UWL) (Xue and Nation, 1984).

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Researchers have also gleaned a list of English headwords or word families in Art, Commerce, Law and Science and have investigated their coverage in textbooks.

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The problem of Fry's word lists is that each list covers many grades at a time; for instance, the life science list covers grades four through nine. With the words alphabetized, it is very difficult for the readers to see which words are appropriate for lower grade levels.

The review

Professionals in content area reading also highly value the comprehension of scientific and technical terms regarding a student's ability to read and learn from textbooks written in English. Singer and Donlan (1989) state that the general English reading books do not as a rule contain scientific and technical terms. A student may have good general reading skills, but still have difficulty in reading materials in a specific field of study. The common type of specialized words with technical meanings and abstract concepts often appear in scientific textbooks encompassing physics, chemistry, astronomy, technology, health and biology. These are quite diverse, if sometimes overlapping, fields. Each has its own special lexis and concepts (Dechant & Smith, 1961, Singer & Donlan, 1989). Such scientific or specialized vocabulary has to be taught (Coxhead, 2006; Nation, 2008; Singer & Donlan, 1989).

In Taiwan, there are no standardized or criterion-referenced tests to assess college students' ability to read science textbooks in English.