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Incidental learning of L2 technical vocabulary through repeated reading of academic texts

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Abstract

This is a case study investigating the effect of repeated reading of academic texts on incidental learning of L2 technical vocabulary. The impact of factors such as frequency of encounters and pictorial contexts on incidental learning of L2 technical vocabulary was also examined. Five adult EAP students were required to read academic texts from different disciplines multiple number of times. Participants' vocabulary gains in receptive knowledge of form-meaning connection and productive knowledge of written form were measured. The results indicated that repeated reading of academic texts promotes incidental learning of L2 technical vocabulary. However, it is also necessary to be aware the impact of individual difference on incidental learning of L2 technical vocabulary. No correlation was found between either frequency of encounters or existence of pictorial contexts and vocabulary gains.

Key words: repeated reading, incidental vocabulary learning, technical vocabulary learning, EAP, frequency of encounters, pictures

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1. Introduction

1.1 The purpose and rationale of the study

The present study investigates the effect of repeated reading (RR) of academic texts on incidental learning of L2 technical vocabulary. The participants were required to read different academic texts different numbers of times. Vocabulary gains were compared in both a within-subject manner and a within-texts/cross-subject manner. The main aim of the study is to understand to what extent do adult L2 learners for academic purposes incidentally learn L2 technical vocabulary through RR of academic texts. The secondary aim is to examine whether frequency of encounters and pictorial contexts affect the incidental learning of L2 technical vocabulary through RR of academic texts.

Several reasons reveal the necessity to conduct the present study. First, it was shown that L2 learners for academic purposes have a heavy burden to learn L2 technical vocabulary (Chung & Nation, 2003; Fraser, 2005; Hu & Nation, 2000; Laufer, 1989; Liu & Nation, 1985; Schmitt et al., 2011). Second, research shows that technical vocabulary can be learned incidentally through academic reading (Parry, 1991; Vidal, 2011). Third, RR is a supportive approach to improving reading comprehension and it should be commonly used in academic reading (Alessi et al., 1989; Barnett & Seefeldt, 1989; Dowhower, 1987; Gorsuch & Taguchi, 2008; Hawkins et al., 2015; Herman, 1985; Millis, Simon, & Tenbroek, 1998; Raney, 2003; Rawson, Dunlosky, & Thiede; 2000; Tenpenny; 1995; Walczyk et al., 2001; Zwaan, Magliano, & Graesser; 1995). Fourth, RR promotes incidental learning of general L2 vocabulary (Han & Chen, 2010; Horst & Meara, 1999; Liu & Todd, 2014; Webb & Chang, 2012). Fifth, earlier findings suggested that some factors such as frequency of encounters and pictorial annotations positively affect the incidental learning of L2 vocabulary (Brown et al., 2008; Chun & Plass, 1996; Kost et al., 1999; Nagy et al, 1985; Plass et al., 1998; Webb, 2007, 2014; Yoshii & Flaitz, 2002; Zahar et al., 2001). Taken together, it is valuable to investigate whether RR of academic texts contributes to incidental learning of L2 technical vocabulary to reduce learning burden of L2 technical vocabulary. It is also necessary to understand the effect of frequency of encounters and pictorial contexts on incidental learning of L2 technical vocabulary through RR of academic texts to determine how these factors affect learning.

1.2 Background

1.2.1 The importance of incidental learning of L2 technical vocabulary

For second language (L2) learners for academic purposes, repeated reading (RR) might be an approach to incidental learning of L2 technical vocabulary. However, so far there has been no prior research concerning this area. Additionally, many factors, such as pictorial annotations (Chun & Plass, 1996; Kost et al., 1999; Plass et al., 1998; Yoshii & Flaitz, 2002) and frequency of encounters of unknown words (Brown et al., 2008; Horst et al., 1998; Vidal, 2003, 2011; Waring & Takaki, 2003; Zhar et al., 2001) affect the incidental learning of unknown L2 words. However, at present, it is unclear the extent to which these factors affect the incidental learning of technical vocabulary through RR. The present study aims to shed light on this.

Technical vocabulary is important for second language (L2) learners for academic purposes. Reading comprehension is largely affected by the proportion of familiar words among all of the running words in texts (Hu & Nation, 2000; Liu & Nation, 1985; Nation, 2013; Nation, 2006). Technical vocabulary accounts for a large proportion of academic texts (Chung & Nation, 2003; Fraser, 2005). Therefore, it is necessary for L2 learners for academic purposes to learn the technical vocabulary in their own disciplines. However, the great number of technical words

(Chung & Nation, 2003; Fraser, 2005) leads to a huge learning burden. Thus, it is necessary to investigate effective approaches to the learning of L2 technical vocabulary.

Vocabulary can be learned intentionally or incidentally (Hulstijn, 2003). This study investigated whether L2 technical vocabulary can be incidentally learned through RR. Hulstijn (2003) suggested that incidental learning is a byproduct in meaning-focused situations where learners are not aware of the post-tests of the byproducts. This byproduct feature of incidental learning of vocabulary indicates that if technical vocabulary can be learned incidentally, the heavy burden of deliberately learning many L2 technical words could be reduced.

Technical vocabulary is a part of knowledge systems of individual disciplines (Nation, 2013). Thus, learning technical vocabulary involves learning both the words and the concepts of the words (Nation, 2013; Godman & Payne, 1981). Academic texts provide rich contexts for learning the concepts of technical words. University students do an enormous amount of academic reading. Thus, incidental learning from academic reading may be a way to incidentally learn L2 technical vocabulary.

Research has shown that technical vocabulary can be learned incidentally through academic reading (Parry, 1991; Vidal, 2011). However, learning L2 technical vocabulary incidentally through only one reading might not be a very effective approach. One important premise of incidental vocabulary learning is the repeated encounters with unknown words. Numerous studies (e.g. Brown et al., 2008; Horst et al., 1998; Nagy et al., 1985, 1987; Rott, 1999; Waring & Takaki, 2003; Webb, 2007; Vidal, 2003, 2011; Zahar et al., 2001) reveal that the more exposures with unfamiliar words, the more likely that the words can be learned incidentally.

To get more exposures with unknown technical words, it is necessary to get enough reading input. Academic language is more difficult to understand than language for daily communication (Cummins, 1999, 2008; Hakuta et al., 2000). In addition, it takes more time to read the same text for L2 readers than for native speakers, even for advanced L2 readers (Bernhardt, 1987; Oller & Tullius, 1973). Thus, given an allocated time, L2 advanced readers receive less reading input of academic language than their native speaking peers. This reduces the possibility of incidental learning of L2 technical vocabulary through academic reading. However, RR provides a way of receiving more encounters with the same unknown technical word for readers.

1.2.2 The potential of learning of L2 technical vocabulary incidentally through RR

RR has been found to be an effective approach to improve reading comprehension when readers fail to understand texts (Alessi et al., 1989; Barnett & Seefeldt, 1989; Dowhower, 1987; Gorsuch & Taguchi, 2008; Hawkins et al., 2015; Herman, 1985; Walczyk et al., 2001). Due to the difficulty of academic language (Cummins, 1999, 2008; Hakuta et al., 2000) especially for beginning L2 academic readers whose reading proficiency is weaker than their native speaking peers, RR is very useful. Prior research indicated that RR is a useful method of learning general L2 vocabulary (Han & Chen, 2010; Horst & Meara, 1999; Liu & Todd, 2014; Webb & Chang, 2012). It was therefore reasonable to propose a positive effect of RR of academic texts on incidental learning of L2 technical words incidentally.

Though research has shown that RR is an effective approach to learning general L2 vocabulary, no studies have examined the effect of reading academic texts repeatedly on incidental learning of technical vocabulary. Most prior studies used graded readers as reading material and only the incidental learning of general vocabulary through RR was investigated.

Academic language is more difficult than general language. Because of the difficulty of academic language, academic readers, especially L2 academic readers might read repeatedly more than the readers of general language texts. Studies concerning this issue were needed.

Apart from whether and to what extent L2 technical vocabulary can be learned through RR of academic texts, it was also valuable to examine the effect of some factors that might affect this learning process. Incidental vocabulary learning is impacted by numerous factors such as pictorial annotations (Chun & Plass, 1996; Kost et al., 1999; Plass et al., 1998; Yoshii & Flaitz, 2002) and frequency within texts (Brown et al., 2008; Horst et al., 1998; Vidal, 2003, 2011; Waring & Takaki, 2003; Zhar et al., 2001). This study examines how incidental learning of L2 technical vocabulary through RR might be influenced by these factors.

1.3 The Method of the study

This is a case study in a pre-test, RR treatment, post-test, and delayed post-test design. There were 5 participants in total. Every participant was asked to read four texts different numbers of times. The four texts are from authentic textbooks from undergraduate programs of North American universities. The incidental vocabulary gains of the participants were measured through an interview based on the interview designed by Schmitt (1998) and a dictation test measuring productive knowledge of written form. The nature of the two tests was not informed to the participants to ensure that the potential vocabulary gains were from incidental learning.

1.4 Human Ethics Requirements

This study was conducted after receiving the approval of Western University Non-Medical Research Ethics Board. The approval notice is attached in the Appendix.

1.5 The Organization of the Thesis

This thesis proposal consists of six parts:

1) Chapter 1: an overall introduction to the topic: learning L2 technical vocabulary incidentally through repeated reading of academic texts;
2) Chapter 2: the necessity to investigate the effect of RR of academic texts on incidental learning of L2 technical vocabulary;
3) Chapter 3: the method used to collect the data;
4) Chapter 4: the results of the study;
5) Chapter 5: the discussion of findings in this study;
6) Chapter 6: a summary of findings, limitations of the present study and directions of future studies.

2. Literature Review

2.1 Introduction

Repeated reading (RR), a commonly used strategy for improving reading comprehension and fluency (Alessi et al., 1979; Hawkins et al., 2015; Walczyk et al., 2001), is an effective approach to building L2 vocabulary knowledge incidentally (Han & Chen, 2010; Horst & Meara, 1999; Liu & Todd, 2014; Webb & Chang, 2012). However, little is known about the effect of RR of academic texts on incidental learning of L2 technical vocabulary.

Technical vocabulary is important to academic reading comprehension (Chung & Nation, 2003; Frazer, 2005; Hu & Nation, 2000; Joshi, 2005; Liu & Nation, 1985; Nation, 2013; Qian, 2002). In addition, Jones and Schmitt (2010) indicated that a lack of disciplinary vocabulary and phrase knowledge is one of the main reasons why international students find academic discussion difficult. However, the huge number of technical words (Chung & Nation, 2003, 2004; Frazer, 2005) leads to a heavy learning burden for L2 or foreign language (FL) learners for academic purposes. It is therefore necessary to examine different approaches to learning L2 technical vocabulary.

Academic texts are usually harder to read than general texts (Cummins, 1999, 2008; Hakuta et al., 2000). However, research has shown that technical vocabulary can be incidentally learned from reading academic texts although there is no prior study specifically focusing on this topic (Parry, 1991; Vidal, 2011). Thus, it is useful to investigate the effects of RR of academic texts on incidental learning of L2 technical vocabulary. If RR, a common complementary reading strategy, facilitates incidental learning of L2 technical vocabulary, it could help to reduce the heavy lexical learning burden to some extent for L2 learners for academic purposes. Thus, the present study aims to investigate:

1) to what extent do adult L2 learners for academic purposes incidentally learn L2 technical vocabulary in academic texts through repeated reading;

2) to what extent do pictorial contexts and the frequency of encounters affect the incidental learning of L2 technical vocabulary of adult L2 learners for academic purposes through reading academic texts repeatedly?

In this literature review, I first introduce why it is valuable to investigate the effect of RR of academic texts on incidental learning of L2 technical vocabulary. This section mainly discusses:

1) what is RR;

2) why RR might be a useful approach for L2 or FL learners for academic purposes to learning L2 technical vocabulary incidentally;

3) what is incidental learning;

4) the effect of reading academic texts on incidental learning of L2 vocabulary;

5) whether RR facilitates incidental learning of L2 vocabulary.

The second section is about learning technical vocabulary. This section includes discussion of:

1) what is technical vocabulary;

2) how to learn technical vocabulary;

3) why it is important to learn it.

Since the present study investigates the incidental learning of technical vocabulary, it is necessary to consider the factors potentially affecting the incidental learning of vocabulary that might also influence the results of this study, such as pictorial contexts and frequency of encounters. This is discussed in the third section.

2.2 Why study the effect of RR of academic texts on L2 incidental vocabulary learning

This section addresses five issues. In the order of elaboration, they are:

1) what is RR;

2) why RR of academic texts could be a useful approach for students learning English for academic purposes (EAP) to learning technical vocabulary incidentally;

3) what is incidental learning;

4) whether L2 technical vocabulary can be learned incidentally through reading academic texts;

5). whether RR promotes incidental learning of L2 vocabulary.

2.2.1 What is repeated reading

RR is a practice used to help reading fluency and comprehension. Based on the automaticity theory (La Berge & Samuels, 1974), a widely-researched definition of RR was developed by Samuels (1979) as a supplementary training method to promote reading fluency of beginning readers. Repeated reading is “Rereading a short, meaningful passage several times until a satisfactory fluency is reached” (Samuels, 1979, p. 377). However, academic texts are much longer than the proposed “short passages” by Samuels (1979). The lengths of reading materials in prior research concerning incidental vocabulary acquisition through RR ranged from the short (Han & Chen, 2010; Webb & Chang, 2012) to the long (Horst & Meara, 1999; Todd & Liu, 2014).

There are two forms of RR: assisted repeated reading (ARR) and unassisted repeated reading (URR). ARR involves multiple, successive readings of one text while listening to an audio version of the text or listening to other people reading aloud while simultaneously reading.

URR involves multiple, successive readings of one text silently or aloud without audio support (Han & Chen, 2010; Samuels, 1979; Todd & Liu, 2014; Webb & Chang, 2012).

Research has indicated that RR is effective for improving reading comprehension, reading fluency and vocabulary learning (incidentally and intentionally) for both first language (L1) and L2 learners (Dowhower, 1987; Gorsuch & Taguchi, 2008; Han & Chen, 2010; Horst & Meara, 1999; LaBerge & Samuels, 1974; Taguchi, 1997; Taguchi & Gorsuch, 2002; Todd & Liu, 2014; Webb & Chang, 2012).

2.2.2 Why study the effect of RR of academic texts on incidental L2 vocabulary learning

This subsection addresses:

1) RR is a commonly used approach to improving reading comprehension by readers when they fail to understand texts;

2) RR facilitates both L1 and L2 reading comprehension and fluency;

3) academic texts are more difficult to read than general texts.

The aim of this subsection is to discuss whether RR is commonly used in academic reading. If RR is not commonly used in academic reading, extra time is needed for RR to learn technical vocabulary. Therefore, even if the present study indicates that RR facilitates incidental learning of L2 technical vocabulary, it could be a less efficient approach to learning L2 technical vocabulary incidentally.

2.2.1.1 RR: a common choice by readers to improve reading comprehension

Research has shown that readers do read repeatedly for better comprehension when they have difficulty understanding reading materials. This strategy is referred to as “rereading”[1] (Alessi et al., 1989; Walczyk et al., 2001). Walczyk et al. (2001) investigated whether readers having reading difficulties use rereading and lookback strategies more frequently for better comprehension than those with a higher reading ability.

Verbal efficiency and working memory were used as predictors of reading ability. Low working memory and low verbal efficiency provide the readers with less attention and working memory available for comprehension in the reading process (Perfetti, 1985; Walczyk et al., 2001). Thus, it is more likely for these readers to have difficulty with reading comprehension. Various tests were used to measure different aspects of the participants’ verbal efficiency and their working memory. These include a word-naming test, a semantic access test, an anaphor resolution test, and a verbal working memory test. The thinking aloud method was used to record the participants’ usage of rereading and lookback.

The results showed that the frequency of rereading ($M=3.25$, $SD=3.28$) significantly correlated with the results of the word-naming test ($N=73$, $M=0.51$, $SD=0.16$, $p<0.05$, $r=0.25$), and with those of the working memory latency ($N=73$, $M=1.81$, $SD=0.88$, $p < 0.05$, $r=0.27$). Also, the frequency of lookback ($M=3.35$, $SD=3.28$) significantly correlated with the results of

a

[1] The difference between rereading and RR is that RR is reading a whole material more than once while rereading is only reading one or several parts of a material multiple times.

the word-naming test (N=73, $M=0.51$, $SD=0.16$, p<0.01, r=049) and with the anaphor accuracy (N=73, $M=16.18$, $SD=2.78$, $p < 0.05$, r= -0.26,).

Overall, the readers with low reading ability employed repetition more frequently in reading than those with high reading ability. This means that readers of complicated texts indeed tend to read repeatedly to improve comprehension.

2.2.1.2 RR benefits both L1 and L2 reading comprehension and fluency

Research on both L1 and L2 reading fluency and comprehension shows that rereading and RR are effective to improve reading comprehension and fluency (Alessi et al., 1983; Barnett & Seefeldt, 1989; Dowhower, 1987; Gorsuch & Taguchi, 2008; Hawkins et al., 2015; Herman, 1985). Dowhower (1987) suggested that RR improves reading rate, fluency, and comprehension of beginning L1 readers. She also stipulated that the gains of reading rate, comprehension, and fluency from RR could transfer to unpracticed texts.

RR also assists L2 reading comprehension and fluency. Taguchi (1997) investigated the effect of RR on L2 reading fluency improvement. The participants read each text 7 times with the 1st time URR reading, the following 3 times ARR reading and the last three times URR. The participants were provided with stopwatches to record their reading time of the initial, the 5th, the 6th and the 7th readings. The study included 28 sessions in which one text was read in each session. The 1st and the last sessions served as the pre-test and the post-test. The reading rates were measured by words read per minute (WPM). Taguchi found that concerning RR of one text (within both the pre-test and the post-test), RR increased reading rate from the 1st reading to the 5th reading, from 5th to 6th reading, and from 6th to 7th reading (Taguchi, 1997, p.109). This indicates that ARR and URR are effective in improving L2 reading fluency of practiced texts. In addition, comparing the reading rate of the initial readings of the pre-test and the post-test, there was an improvement from the pre-test to the post-test. The results also indicated that the reading fluency gains from RR could transfer from the practiced texts to new texts.

Taguchi and Gorsuch (2002) and Gorsuch and Taguchi (2008) investigated the effect of RR on L2 readers' improvement of both reading comprehension and fluency. The design of these two studies was similar to that of Taguchi (1997). The reading rate was still measured by WPM. The first and the last RR sessions still served as the pre-test and the post-test of reading fluency. Additionally, to measure the reading comprehension gains from RR, there was a pre-test reading session and a post-test reading session before and after the RR treatment. In both studies, the participants read the test passages 7 or 5 times. In Taguchi and Gorsuch (2002) the participants took a comprehension test after the 1st, 3rd and the 7th reading in both pre-test and post-test sessions of reading comprehension. In Gorsuch and Taguchi (2008), the participants took a comprehension test after the 1st, 3rd, and the 5th reading in both test sessions of reading comprehension. The reading texts in the pre-test and the post-test sessions were different from the ones in the RR sessions. The reading comprehension tests in both the pre-test and the post-test in Taguchi and Gorsuch (2002) contained ten open questions. The reading comprehension tests in Gorsuch and Taguchi (2008) also contained a recall test in both the pre-test and the post-test apart from the open question tests.

Comparing the reading rate of the 1st readings of the pre-test and of the post-test, there were significant improvements in the experimental group in both studies: the mean WPM went up from 113.25 to 153.50 (p = 0.0134) in the Taguchi and Gorsuch (2002) study; this number increased from 163.20 to 216.78 ($p < 0.025$) in their 2008 study. Thus, RR facilitates L2 reading fluency improvement. It also indicates that the gains of reading fluency from RR could transfer from practiced texts to new texts. Comparing the reading comprehension scores of the experimental group within the pre-test and within the post-test, there were significant improvement from the initial reading to the last reading in both studies. This indicates that RR also facilitates L2 reading comprehension.

The possible reasons why RR facilitates reading comprehension are:

1) RR or rereading improves the rate of word recognition across multiple readings (Raney, 2003; Tenpenny; 1995).

2) Across the multiple readings of one text, the lower-level understanding of individual words and sentences transfers from the initial reading to later readings. Thus, in later readings, readers could allocate more attention on overall contexts and episodes of texts. This contributes to overall comprehension of texts (Millis, Simon, & Tenbroek, 1998; Zwaan, Magliano, & Graesser; 1995);

3) RR facilitates readers' ability of metacomprehension so that readers can monitor their comprehension more precisely. The readers therefore could in time employ compensatory strategies (Rawson, Dunlosky, & Thiede; 2000).

4) Rereading helps readers to "go back to look at prerequisite information missed, misunderstood or forgotten (e.g. looking back in the text, rereading, or referring to previously taken notes)" (Alessi et al., 1983, p.3).

Taken together, the research suggests that RR is used by readers frequently when they have difficulty in reading comprehension; less proficient readers do RR or rereading more frequently than proficient readers. This may be more common if the texts are more difficult, such as academic texts (this will be addressed in the following section). L2 readers are also slower in word decoding (Oller & Tullius, 1973) than native speakers. This is true of both good and poor L2 readers (Bernhardt, 1987). Thus, L2 academic readers might need more cognitive capacity for efficient reading than native speakers. Thus, reading academic texts repeatedly might be commonly used by L2 academic readers. As discussed, RR is an effective approach to improve both L1 and L2 reading comprehension and fluency development. Therefore, whether this "deceptively simple but extraordinary powerful" (Dowhower, 1994, p. 343) method also contributes to the incidental learning of L2 technical vocabulary was investigated in this study.

2.2.1.3 RR: an effective strategy to improve reading comprehension when reading academic texts

As discussed above, readers should do RR more frequently when reading more difficult texts. This subsection aims to justify that academic texts are more difficult to understand than general texts. If so, we might assume that academic readers, especially beginning academic readers do RR frequently.

Cummins (1999, 2008) and Uccelli (2015) proposed that academic language is more difficult and that it takes more time to be learned than learning general communicative language. According to Cummins (1999, 2008), language proficiency can be divided into basic interpersonal communicative skills (BICS) and cognitive academic language proficiency (CALP). "BICS refers to conversational fluency in a language while CALP refers to students' ability to understand and express, in both oral and written modes, concepts and ideas that are relevant to success in school" (Cummins, 2008, p. 487). Cummins' (2008) proposed that it takes more time to acquire CALP skills than to get BICS skills, and Hakuta et al.'s (2000) data provided support for this.

In addition, with the difficulty of academic language, learning vocabulary incidentally from repeated reading of general texts and from repeated reading of academic texts might be different. Considering that readers read repeatedly when they have difficulty in comprehension, it is likely that they often read repeatedly when they read academic texts. Given the positive effect of RR on incidental learning of general vocabulary (Han & Chen, 2010; Horst & Meara, 1999; Todd & Liu, 2014; Webb & Chang, 2012), it could be reasonable to propose a positive effect of RR of academic texts on learning vocabulary. In addition, RR facilitates readers' reading comprehension development which also positively affects learning vocabulary (Nation, 2013).

However, with the difficulty of academic language, it's also possible for readers to have low lexical coverage of academic texts. Lexical coverage refers to the proportion of known words in a text. High lexical coverage helps readers to guess the meanings of unfamiliar words from contexts correctly (Liu & Nation, 1985). Thus, unknown words in academic texts may be difficult to learn.

Thus, given this difference between academic texts and general texts and the complicated situation of learning vocabulary from academic contexts, it is hard to generalize the findings from the research concerning learning L2 vocabulary through RR of general texts to that through reading academic texts.

Taken as a whole, it is likely that readers do RR more frequently when they read difficult materials. Research suggested that academic texts are more difficult than general texts. Thus, readers of academic texts might do RR more than those of general language. Thus, it is useful to investigate whether RR also benefits incidental learning of L2 technical vocabulary from academic texts.

2.2.3 What is incidental learning

Vocabulary can be learned incidentally or intentionally. However, researchers have not reached a consensus on the definition of incidental learning. The present study defines incidental learning as meaning-focused learning in which learners read for comprehension and are not informed of the vocabulary acquisition aims of the study (Hulstijn, 2003). As Hulstijn (2003) indicated, both intentional and incidental learning involve attention and cognitive processes, but to different degrees. To ensure that the participants of the study learn the target words incidentally, they were not informed of the aims of the study. Rather, they were told that the study is to investigate the effect of RR on academic reading efficiency improvement.

2.2.4 Incidental learning of technical vocabulary through reading academic texts

Research indicates that technical vocabulary can be learned incidentally through reading academic texts (Parry, 1991; Vidal, 2011). Parry (1991) suggested that relatively little knowledge of technical vocabulary was incidentally learned through academic reading.

With an extended study, Vidal (2011) examined the effect of academic reading on the incidental learning of L2 vocabulary with the consideration of several factors, such as frequency of target words within the reading materials, types of words (academic words, low-frequency words, and technical words), and types of elaboration (explicit elaboration, implicit elaboration, and no elaboration). One hundred and eighteen undergraduate students learning English for specialized purposes (ESP) were assigned into a reading group (N=80) or control group (N=38). These participants were in different English proficiency levels. Three academic texts from difference disciplines were used as reading materials. Thirty-six items (including academic words, technical words and low-frequency words) were selected as target words. These words varied on their elaboration (explicit elaboration, implicit elaboration, and no elaboration) and frequency.

In the pre-test, immediate post-test, and the delayed post-test, the participants were required:

1) to verify whether they encountered the words,

2) to provide detailed meanings of the words, to translate the words into Spanish (their L1),

3) to make a sentence using the words.

The scoring system was based on a modified Vocabulary Knowledge Scale (VKS). Before the treatment, the participants were tested on their knowledge of the target words, and there was an immediate post-test and a delayed post-test.

The results showed that for the reading group, there was a significant difference between the pre-test (M=1.82, SD=2.66) and the immediate post-test (M=42.67, SD=20.67), and between the pre-test (M=1.82, SD=2.66) and the delayed post-test (M=20.96, SD=12.64) with p<0.001. However, there was no significant difference among the vocabulary tests of the control group. Comparing the acquisition of different types of target words in the reading group (academic words, low-frequency words, and technical words), though some technical words were learned, it is not clear how many technical words were learned exactly. The results of the study also showed that the more frequent a target word in the reading materials is, the more possible it is learned incidentally through academic reading.

To sum up, technical vocabulary can be learned incidentally through academic reading. Some factors, such as the frequency of the words and the method of elaboration of the words also correlate with the efficiency of incidental learning of L2 technical vocabulary through academic reading. However, so far there has been no research specifically focuses on the incidental learning of L2 technical vocabulary through academic reading.

2.2.5 RR and incidental learning of general vocabulary

Some studies examined the effect of RR on incidental learning of L2 general vocabulary (Han & Chen, 2010; Horst & Meara, 1999; Liu & Todd, 2014; Webb & Chang, 2012). Webb and Chang (2012) compared the effect of ARR and URR on incidental vocabulary learning of L2 beginners. This study contained pre-tests, post-tests, and RR treatments. Each pre-test and its paired post-test were the same. Eighty-two Chinese native speakers learning English as a foreign language (EFL) were randomly assigned to either the ARR treatment group or the URR treatment group. Both groups received two semesters of RR treatments. Before and after each treatment, they received a pre-test and a post-test respectively (labeled as Test A and Test B for the first and the second semesters respectively). A modified rating scale, VKS, was used to measure knowledge of target words. In this measurement, the participants were required to evaluate their knowledge of each target word by themselves using the VKS. In each RR treatment, the students were required to read 14 stories (two stories per week) over 7 weeks. They read each story at least twice. In the ARR group, the participants read with the simultaneous audio version of the stories. In the URR group there was no audio support.

Paired-samples t-tests revealed that for both the ARR group and the URR group, the number of the words that participants had no knowledge about statistically significantly decreased from pre-tests to post tests. Test A showed that the mean number of the target words that the participants had no knowledge about decreased from 23.89 (*SD*= 9.01) in the pre-test to 17.65 (*SD*=10.68) in the post-test for URR group. Likewise, this figure for ARR group decreased from 27.69 (*SD*=11.81) in the pre-test to 14.42 (*SD*=10.89) in the post-test. Test B showed that the mean number of the target words that the participants knew nothing about before the treatment decreased from 18.43 (*SD*=9.43) to 11.19 (*SD*=8.90) for URR group and that for the ARR group this number decreased from 25.47 (*SD*=10.78) to 8.93 (*SD*=9.06).

The number of the words whose meanings were known by the participants significantly increased from the pre-test to the post test. Test A showed that the mean number of the target words whose meanings were known by the participants increased from 5.37 (*SD*=5.52) in the pre-test to 7.87 (*SD*=6.29) in the post-test for URR group. Likewise, this figure for the ARR group increased from 4.86 (*SD*=2.50) in the pre-test to 15.61 (*SD*=9.91) in the post-test. Test B showed similar results. The mean number of the target words whose meanings were known by the participants increased from 6.62 (*SD*=3.38) in the pre-test to 11.57 (*SD*=6.61) in the post-test for URR group. Likewise, this figure for the ARR increased from 7.97 (*SD*=7.44) in the pre-test to 20.10 (*SD*=10.10) in the post-test. An ANOVA test also confirmed that both groups did better significantly in the post-tests than in the pre-tests.

Horst and Meara (1999) suggested that with the increase of readings, the vocabulary gains increase. A 52-year old English native speaker learning Dutch as a FL read a 6000-words comic (with a huge number of pictures) 8 times in total. The target words were the ones appearing only once in the text and there were 300 of them in total. During the treatment, the participant read the whole article once each Saturday and did an assessment of the target words (post-tests) on the following Wednesday. Seven days before the treatment, the participant received a pre-test of the target words. The post-tests and the pre-test were the same in which the participant evaluated his knowledge of the target words with a 4-item scale self-evaluation test.

The results showed that the participant's knowledge of the target words sharply increased. The number of words identified as "I definitely don't know what this word means" decreased from 114 in the pre-test to 81 after the 1st reading, to 72 after the 2nd reading, to 57 after the 3rd reading, to 48 after the 4th reading, to 40 after the 5th reading, to 39 after the 7th reading, and to 30 after the last reading. The number of words identified as "I'm not really sure what this word means" dropped from 50 in the pre-test, to around 30 after 5 readings, and to around 25 after 6 or 7 readings, and to 20 after the last reading. The number of the words identified as "I think I know what this word means" dropped from 54 in the pre-test to 49 after the 1st reading, to 37 after the 2nd and the 3rd reading, to 31 after the 6th reading, to 28 after the 7th reading, and to 27 after the 8th reading. In contrast, the number of the words identified as "I definitely know what this word means" sharply increased from 82 in the pre-test to 119 after the 1st reading, to 164 after the 3nd reading, to 173 after the 3rd reading, to 181 after the 4th reading, to 191 after the 5th reading, to 200 after the 6th reading, to 209 after the 7th reading, and to 223 after the last reading.

However, both studies by Horst and Meara (1999) and by Webb and Chang (2012) used self-evaluation tests. Though this type of test emphasizes the importance of sensitive measures of vocabulary gains, it suffers from some limitations (Nation & Webb, 2011; Read, 2000; Schmitt, 2010). Nagy et al. (1985, 1987) indicated that vocabulary learning occurs on a continuum with numerous increments of knowledge. This suggests a problem with developing a self-evaluation scale: how many stages are necessary? Webb and Chang (2012) used a three-stage scale while Horst and Meara (1999) used a four-stage scale. However, it is not clear whether the three or the four stages were reasonable. Whether the intervals between the stages are consistent or not is also unclear in these studies. Another limitation is that to self-evaluate vocabulary knowledge, the participants should be able to make metalinguistic judgements. However, it is not clear whether all the participants have this ability. This limitation is revealed in the study by Horst and

Meara (1999). Thus, considering the limitations of the measures, further studies were needed to investigate the effect of RR on incidental learning of L2 vocabulary.

Han and Chen (2010) examined the effect of RR on incidental learning of both receptive and productive vocabulary knowledge of a single L2 learner of Chinese. Their findings also indicated that RR is effective on helping incidental learning of vocabulary. In addition, they also suggested that RR is more effective in improving receptive vocabulary knowledge than on improving productive vocabulary knowledge. Diverse aspects of vocabulary gains were measured receptively and productively, including the written forms of the words and the meanings of the words.

However, the tested words for measuring the participant's incidental learning were picked from those that the participant orally read incorrectly. Thus, it was hard to ensure that the participant had no previous knowledge of other aspects apart from the spoken forms of these words prior to the RR treatment. There was also no pre-test of the words. Thus, it is not clear whether the vocabulary knowledge gains reveled in the tests really resulted from incidental learning or from previous knowledge.

Todd and Liu (2014) also found a positive influence of RR on incidental learning of L2 vocabulary. They examined the effect of RR on incidental learning of L2 vocabulary with Chinese native speakers learning Japanese as a FL. This study contained a pre-test, a RR treatment, and a post-test. Multiple choice test was used to measure the participants' knowledge of target words. During the treatment, 3/4 of the participants in the RR group read while listening to one text seven times (ARR) successively. The other 1/4 of participants did the same without listening to the audio version of the text (URR).

For the overall RR group, there was a significant improvement from their pre-test scores to their post-test scores (*M*=10.34, *t*=58.45, $p < 0.05$). However, 3/4 of the participants in the ARR group either shadowed (shadowing every word read in the audio version of the text), or time-lapse imitated (repeating as many words as possible at the end of a sentence read in the audio version), or subvocalizated (shadowing the audio version without reading aloud) the reading texts when doing RR. It's not clear whether all these phonological practices were ecologically valid RR methods. Furthermore, it is possible that additional attention was drawn by the phonological practices of the spoken forms of the words (to shadow or to say the words simultaneously or with a time lapse). In this case, it is hard to tell whether the vocabulary gains were from incidental or intentional learning. In addition, the multiple-choice test used in this study was not sensitive to partial knowledge gains because "the formal distractor choices only differ from the correct target word by a morpheme" (Todd & Liu, 2014, p. 61).

Despite of the various limitations, these studies indicate that RR may promote incidental learning of L2 vocabulary. RR may thus be a useful strategy for incidental vocabulary acquisition during L2 academic reading. L2 or FL learners for academic purposes face the heavy burden of technical vocabulary learning. Academic reading is effective for developing L2 technical vocabulary even though it is unclear how much technical vocabulary can be learned exactly. To find efficient approaches to reducing the learning burden of L2 technical vocabulary, the degree to which RR facilitates incidental learning of technical vocabulary from academic texts was examined in the present study.

However, even though research has shown the positive effect of RR on incidental learning of L2 vocabulary, none of the studies address the effect of RR on incidental learning of L2 vocabulary in academic texts. As discussed, academic texts are more difficult to read than general texts which may affect the efficiency of incidental learning of L2 vocabulary. Thus, given this difference between academic texts and general texts and the complicated situation of learning vocabulary from academic contexts, it is therefore unreasonable to generalize the earlier findings concerning the effect of reading general texts repeatedly on incidental learning of L2 general vocabulary to the field of incidental learning of L2 technical vocabulary through RR of academic texts.

2.3 Technical Vocabulary

The present study investigated the effect of RR of academic texts on incidental learning of L2 technical vocabulary. Due to the large number of technical words and the importance of vocabulary knowledge on reading comprehension (Hu & Nation, 2000; Liu & Nation, 1985; Nation, 2006; Nation, 2013), technical vocabulary is important for academic success. Thus, it's valuable to find effective approaches to learning technical words. In this section, the following issues will be discussed:

1) what is technical vocabulary;

2) the importance of learning technical vocabulary;

3) how to learn technical vocabulary.

To understand technical vocabulary, the high-, mid-, low-frequency words, and specialised words should be understood, and so are addressed first.

2.3.1 High-, mid-, and low- frequency words

Words are different in their frequency. Frequency is the number of times a word occurs in a language. According to Nation (2013), L2 learners can use a relatively small number of highly repeated (frequent) words to do a lot. Thus, to L2 learners, words are of different values to learn. The more frequent a word is, the more valuable it is to be learned. The more valuable words should be learned earlier than the less valuable ones. To make it convenient to design vocabulary learning plans for L2 or FL learners, vocabulary has been categorized into 4 groups according to their frequency: high-frequency words, mid-frequency words, low-frequency words, and specialized vocabulary including technical vocabulary.

The high-frequency words in English are the 2000 most frequent word families (Chung & Nation, 2003; Nation, 2013; West, 1953). They account for 70% -- 90% of all the running words of both written and spoken texts in English. Based on West (1953), these words serve all types of English texts. Readers need to know at least 98% of all the running words of a text to get an adequate comprehension of the it (Hu & Nation, 2000; Schmitt et al., 2011). Thus, to reach this lexical coverage, high-frequency words are crucial and so should be learned first. Knowledge of 8000-9000 word families is necessary to get a 98% lexical coverage of various types of written texts (Nation, 2006). Knowledge of 6000-7000 word families is necessary to get a 98% lexical coverage of various types of spoken texts (Nation, 2006). Thus, apart from the 2000 high-frequency word families, the mid-frequency words which are the following 6000-7000 word families are also very important for L2 learners. Other word families apart from high- and mid-frequency word families are low-frequency words. Low-frequency words consist of some technical words and words representing concepts that rarely appear.

In certain types of texts and contexts, some specific words occur very frequently but not that frequently outside of these texts and contexts (Nation, 2013). "Special vocabularies are made by systematically restricting the range of topics or language uses investigated" (Nation, 2013, p. 30). They take account of a large proportion of words in specific texts so that readers and communicators may have difficulty in comprehension if they do not know the words. These words are specialised vocabulary. One category of specialised vocabulary, technical vocabulary, deserves academic language learners' high attention (Nation, 2013; Chung & Nation, 2003, 2004).

2.3.2 What is technical vocabulary

Technical vocabulary is defined as the vocabulary that commonly appears in academic texts of a specific discipline while rarely appearing out of the discipline and they are included as a part of the knowledge system of that discipline (Chung & Nation, 2003, 2004; Nation, 2013). Few studies address the learning of technical vocabulary and one of the possible reasons is that it is hard to identify technical words.

Taking an example of an anatomy text, Table 1 (Chung & Nation, 2003, p. 105) suggests a reliable approach, using a rating scale, to identifying technical vocabulary in academic texts. This rating scale was developed according to the closeness of words' meanings to the knowledge system of anatomy. The words that meet the criteria in Point 3 and Point 4 are considered as technical vocabulary of anatomy. It is necessary to note that not all the technical words are low frequency words. As shown in Table 1, some of them, especially the technical vocabulary in Point 3, occur quite frequently in general language.

*Table 1*A rating scale for determining technical words in anatomy texts (Chung and Nation, 2003, p.105)

Point 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, 12, adjacent, amounts, common, commonly, directly, constantly, early,* and *especially*.
Point 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, lodges, protects*.
Point 3	Words that have a meaning that is closely related to the field of anatomy. They refer to parts, structures or functions of the body, such as the region of the body and systems of the body. Such words are also used in general language. The words may have some restrictions of usage depending on the subject field. Examples are: *chest, trunk, neck, abdomen, ribs, breast, cage, cavity, shoulder, gridle, skin, muscles, wall, heart, lungs, organs, liver, bony, abdominal, breathing*. Words in this category may be technical terms in specific field like anatomy and yet may occur with the same meaning in other fields and not be technical terms in those fields.
Point 4	Words that have a meaning specific to the field of anatomy and are not likely to be known in general language. They refer to structures and functions of the body. These words have clear restrictions of usage depending on the subject field. Examples are: *thorax, sternum, costal, vertebrae, pectoral, fascia, trachea, mammary, periosteum, hematopoietic, pectoralis, viscera, intervertebral, demifacets, pedicle*.

Note: This table is adopted from Chung and Nation (2003, p. 105).

Based on the definition of technical vocabulary, Chung and Nation (2004) introduced some other approaches apart from developing rating scales to identifying the technical vocabulary in academic texts:

1. Technical vocabulary occurs within a specific discipline. It rarely appears outside the discipline. We could compare the frequency of a word within a discipline with its frequency out of the field. If the frequency within the discipline is much higher than that outside the discipline, it's highly possible that the word is a technical word of that discipline.

2. Technical vocabulary serves as a part of the knowledge system of a discipline. Thus, a specialist in the discipline can be referred to in order to identify technical vocabulary. Other than a specialist in person, a technical dictionary can also be consulted to identify technical vocabulary.
3. In technical texts, sometimes authors indicate the technical words with some signals such as bold or italic type. Sometimes the authors will introduce their definitions in texts with examples, pictures, or even direct definitions. These signals can be used to identify technical words.
4. The last approach is using specialized software to identify technical words. There are two types of software determined to identify technical vocabulary: those designed based on a statistical approach and those designed based on a linguistics approach. In statistics approach software, the frequency of words in a corpus of a specialised discipline and that in a non-technical corpus are compared. In linguistics approach software, "linguistic cues such as word form analysis, part of speech, grammatical structure of possible terms such as noun-noun or adjective-noun structures, lemmatization for inflected forms and/or tokenisation to identify word boundaries using a tagged and/or parsed corpus" are used to identify possible technical vocabulary (Chung and Nation, 2004, p. 258). To identify technical vocabulary, then the possible technical words are entered into a system based on frequency comparisons within and outside the specific field.

2.3.3 Why it is important to learn technical vocabulary

Vocabulary knowledge is important to reading comprehension. Technical vocabulary takes account of a large proportion of running words in academic texts. Thus, for learners learning an L2 or FL for academic purposes, technical vocabulary is very important. It deserves learners' and teachers' attention. Readers need to know most words in a text to get an adequate comprehension and to guess the unknown words in the text (Hu & Nation, 2000; Laufer, 1989; Liu & Nation, 1985; Schmitt et al., 2011). Hu and Nation (2000) suggested that readers need to know at least 98% of all the running words of a text to get an adequate comprehension of it. Laufer (1989) suggested that this threshold is 95% of all the running words of reading texts. Chung and Nation (2003) found that in an anatomy text, technical vocabulary may take account of over 30% of all the running words. They also found that in an applied linguistics text, technical vocabulary still takes account of 20.6% of all the running words (Chung & Nation, 2003). This means that in the anatomy text, there is one technical word in almost every three running words and in the applied linguistics text, there is one technical word in every five running words. It is necessary to note that from discipline to discipline, the proportion of technical vocabulary might be different. Even though, in disciplines where technical vocabulary takes account of a lower proportion than that in other disciplines such as applied linguistics, the proportion of technical vocabulary is still high enough to affect reading comprehension. Therefore, the learning burden of technical vocabulary could be very heavy for those learning English for academic purposes (EAP).

2.3.4 How to learn technical vocabulary

The technical words should be learned along with the knowledge system in which the technical words are contained (Nation, 2013). Godman and Payne (1981) suggested that unless the relevant knowledge is well known, it is usually hard to understand or to remember technical words. Thus, different from learning general vocabulary for daily personal communication when adult L2 or FL learners often only need to "relabel" an already known concept, learning L2 technical vocabulary involves learning the professional concepts of the words as well. Learning technical vocabulary in informative contexts that illustrate the knowledge behind the words therefore should be a good approach to learning technical vocabulary. As revealed in previous research, L2 technical vocabulary can be learned from academic reading. The rich contexts for illustrating technical concepts might be one reason why this could happen. This might be one of the reasons why L2 technical vocabulary can be learned incidentally through academic reading. Given that L2 readers use RR frequently, that L2 and FL learners for academic purposes have a heavy burden of learning technical vocabulary, and that technical vocabulary should be learned within the disciplinary knowledge contexts, it is reasonable to investigate whether the L2 and FL learners for academic purposes could incidentally learn technical vocabulary through RR of academic texts.

It is necessary to investigate whether technical vocabulary can be incidentally learned through academic reading which explains technical knowledge or concepts. As discussed earlier, the learning burden of technical vocabulary for those EAP students is heavy. Godman and Payne (1981) also suggested that technical vocabulary should be learned along with the concept or knowledge behind the words.

2.4 Factors affecting incidental acquisition of L2 technical vocabulary

Research has shown that incidental learning of L2 vocabulary is highly associated with various factors such as frequency of encounters of unknown words and pictorial annotations. The current study investigateed the effect of RR of academic texts on incidental learning of L2 technical vocabulary. Thus, it is possible that these factors would also affect the effect of RR of academic texts on incidental learning of technical vocabulary. This subsection aims to 1) elaborate the effects of these factors, namely, frequency of encounters and pictorial annotations on the efficiency of incidental L2 vocabulary learning and to 2) justify the need to examine their effects on the results of the present study.

Repetition of unknown words within learning materials is an important factor impacting incidental learning of vocabulary. Readers can incidentally gain some vocabulary knowledge of unfamiliar words through repeated exposures to contexts containing these words (Nagy et al, 1985; Webb, 2014). Brown et al. (2008), Zahar et al. (2001) and Webb (2007, 2014) suggested that the more encounters with unfamiliar words, the more likely that learners could learn the words incidentally. Nagy et al. (1985) indicated that every encounter with unfamiliar words benefits learners with small incremental gains of vocabulary knowledge. Webb (2007, p. 59) elaborated that "gains in all aspects of knowledge tended to increase as the number of the presentations increased". In all these studies, the target words were encountered with a different number of times by participants and the results showed a significant positive correlation between the vocabulary knowledge scores (on diverse aspects of vocabulary knowledge) and the number of encounters with unfamiliar words. Thus, because RR provides readers with multiple encounters of unfamiliar words, there should be a greater possibility of incidentally learning of vocabulary through RR. In addition, Vidal (2011) found that frequency is a significant contributor of efficiency of incidental learning of L2 vocabulary from academic reading.

Previous research concerning the effect of frequency (repetition) of encounters on incidental vocabulary learning is highly valuable because it emphasized the importance of repetition on incidental vocabulary learning. However, as discussed, academic reading is more difficult than general reading; and learning technical vocabulary is different from learning general vocabulary. Thus, frequency might or might not be a significant contributor to the efficiency of incidental learning of L2 technical vocabulary through RR of academic texts. The present study therefore also investigated whether and how frequency of technical words within texts affects incidental learning of L2 technical vocabulary through RR of academic texts.

Apart from frequency within texts, research has shown that picture illustrations (Chun & Plass, 1996; Kost et al., 1999; Plass et al., 1998; Yoshii & Flaitz, 2002) also affect the efficiency of incidental vocabulary learning through reading. In academic texts, figures and tables are commonly used to illustrate the concepts. These pictures, figures, or tables might also affect the incidental learning of L2 technical vocabulary. Yoshii and Flaitz (2002) investigated the effect of textual annotations, pictorial annotations, and pictorial and textual combined annotations in reading texts on incidental vocabulary learning through reading. The participants under the text-only condition read materials with text-only annotations of target words; those under the picture-only condition read materials with picture-only annotations of the target words; those under the text-and-picture combination condition read materials with picture and text combined annotations of the target words. The participants took a pre-test before the treatment. After the treatment, they took an immediate post test. A delayed post test followed two weeks later. In all the three tests, the participants took:

1) a definition supply test in which the students provided the meanings of the target words productively,

2) a picture recognition test in which the subjects were asked to select one picture from four to identify the meaning of a given word,

3) a word recognition test in which the subjects selected one correct definition from four choices.

The results showed that the participants in the text-and-picture combination group (N=50) significantly outperformed those in the text-only group (N=50) and those in the picture-only group (*N*=51) in all the three measures of both the intermediate post-test and the delayed post-test. This means that when the unfamiliar words are illustrated by both texts and pictures, they are significantly more likely to be learned incidentally by L2 or FL students. This study confirms the findings of previous studies by Chun and Plass (1996), Kost et al. (1999) and Plass et al. (1998). Thus, the figures and tables commonly used by academic writers might promote the incidental learning of L2 technical vocabulary. This is why the effect of pictorial contexts in academic texts on incidental learning of L2 technical vocabulary through RR was also investigated in this study.

To sum up, previous research indicates that pictorial contexts and frequency of encounters with unknown words within texts may affect incidental learning of general L2 vocabulary. To investigate the efficiency of RR of academic texts on incidental learning of L2 technical vocabulary, the influence of these factors was considered in the present study.

Taken as a whole, the heavy burden of learning technical vocabulary by L2 learners for academic purposes indicates that it is useful to investigate effective methods to learn L2 technical vocabulary. Given that RR is a commonly used strategy in academic reading to improve comprehension; that there is potential to learn technical vocabulary incidentally through academic reading; and that there is potential to learn general L2 vocabulary through RR, it was likely that L2 technical vocabulary might be learned incidentally through RR of academic texts. The factors contributing to the effectiveness of incidental learning of L2 vocabulary were also considered to determine the effect of RR of academic texts on incidental learning of L2 technical vocabulary as accurately as possible. Thus, the following research questions were to be addressed:

1. To what extent do adult L2 learners for academic purposes incidentally learn L2 technical vocabulary in academic texts through repeated reading;
2. To what extent do pictorial contexts and the frequency of encounters with the technical words affect the incidental learning of L2 technical vocabulary of adult L2 learners for academic purposes through reading academic texts repeatedly?

3. Method

This section describes the methodology by which the data on incidental learning of L2 technical vocabulary through RR of academic texts was collected. First, the participants of the study will be introduced, followed by a detailed account of the reading materials. Then the process by which the target words were selected is described. An introduction to the measurements follows. Finally, the procedure to collect the data is described.

3.1 The participants

Five university students in Ontario, Canada voluntarily participated in the present study. They were studying or intended to study different disciplines. Their L1s are either Chinese or Arabic and none of them had ever resided in other English-speaking countries before coming to Canada. Most of them had learned English for a long time (except for participant 3) and they learned and used English for academic purposes. However, their academic English level varied to a large extent. Details about the participants are reported in Table 2. As shown in Table 2, the participants are those using English as a second language for academic purposes. Additionally, they are representative of EAP students who are different in English proficiency, academic English learning experience, and majors. Table 2 also shows their length of residence in English speaking regions, time span of learning English, academic English learning experience, and that their majors in universities vary to a large extent.

The Updated Vocabulary Levels Test (UVLT) (Webb, Sasao, & Ballance, 2017) was used to assess the vocabulary proficiency of participants. The residency time in English-speaking countries was also used to estimate participants' English proficiency. Kinginger (2011) and Loewen (2014) suggested that study abroad is an effective way to enhance L2 proficiency.

Hakuta et al. (2000) also suggested that long residency times in English-speaking countries promotes academic English proficiency.

Most of the participants, except for participant 4, had only resided in English-speaking countries (Canada) for a short time. Participant 1, 2, 3, and 5 had stayed in Canada for 11 months, 12 months, 23 months, and 12 months at the beginning of the present study, respectively. Participant 4 stayed in Canada for 10 years. This indicates that participant 4 might have the highest academic English proficiency. It is necessary to note that when participant 3 arrived in Canada, her English proficiency was much lower than others although the residency time in Canada of participant 3 was also higher than three other people.

Three out of five participants (Participants 2, 3, and 5) had been involved in academic English learning before coming to Canada. They took English immersion programs in science subjects, such as Math and Physics in high school. However, academic English proficiency of teachers and students in such programs vary largely. As the participants described, mostly the teachers would teach the programs in their L1, Arabic, due to the limited English proficiency of both teachers and students. However, the concepts such as the arithmetic progression in math were termed in English. For instance, participant 3's English immersion classes were totally in Arabic and Participants 2 and 5's immersion programs were mostly in Arabic. Participant 5 was in the immersion program for 5 to 6 years; participant 2 stayed in the program for 2 years; participant 3 stayed in such a program for only 1 year. These three participants' English language proficiency before joining the English immersion programs was described as very limited. For instance, as participant 3 finished the English immersion program, her English proficiency was evaluated and described by PBLA (Portfolio-Based Language Assessment, a Canadian countrywide English proficiency benchmark) as being able to understand very short, simple social messages such as a short email with the details for an appointment.

Participant 4 had resided in Canada for 10 years. He took his high school, undergraduate, and Master's level education in English in Canada though his English proficiency was very limited before coming to Canada. Additionally, from both his UVLT result and his way of talking during a form-meaning connection interview test during the study, it could be observed that he has a high level of academic English proficiency.

Participant 1 accepted no formal academic English education. It is necessary to note that most English education in China is "teaching to the test" oriented, although she had learned English for 17 years in China, and taken English classes for around 3.5 hours/week at most. For 6 months before coming to Canada, she specifically self-studied English to prepare for the IELTS Academic test. Her score on IELTS before coming to Canada was 6.5 with 6 to 6.5 in the reading test. Since arriving in Canada, she has entered a PhD program.

Table 2 A detailed description of participants' English proficiency and academic background

Participant ID	1	2	3	4	5
age	26	21	21	26	22
Gender	Female	Male	Female	Male	Female
L1	Chinese (Mandarin)	Arabic (Middle East Arabic)	Arabic (Middle East Arabic)	Chinese (Mandarin)	Arabic (Middle East Arabic)
Home country	China	Syria	Syria	China	Syria
Other language learning experience	No other language learning experience	4 to 5 years of French learning, beginner level; one year of German learning experience, beginner level	4 years of French learning experience, beginner level.	3 months of French learning experience, beginner level; self-learning Russian for 5 years, beginner level	No other language learning experience
Total time learning English (years)	17 years	13.5 years	3 -4 years	18 years	12 years
Time involved in EAP programs (months)	0 month	4 months	16 months	24 months	3 months
Academic English learning before coming to English speaking country	6 months (self-studying to prepare for IELTS test)	2 years of high school level English immersion science program	1 year of high school level English immersion science program	0 month	5 to 6 years of high school level English immersion science program
Time staying in English-speaking country (months)	11 months	12 months	23 months	10 years	12 months
Experience using English for academic purpose after EAP programs	11 months in Canada as a PhD student	Being a 2nd year undergraduate student in Canada	No experience	Staying in Canada since grade 10 (1st year high school) to the	Being a 1st year undergraduate student in Canada

Participant ID	1	2	3	4	5
				current Master's program	
Major or the major intended going to	Chemical engineering	Civil engineering	Biology (with very limited biological background knowledge)	Chemical engineer	Physics
Year of study	1st year PhD	2nd year undergraduate	Undergraduate (not started yet)	2nd year Master's	1st year undergraduate
UVLT score — Current levels following levels	3000 level: 28/30 4000 level: 24/30	3000 level: 30/30 4000 level: 24/30	5000 level: 30/30 6000 level: N/A	3000 level: 28/30 4000 level: 24/30	4000 level: 26/30 5000 level: 23/30

All of the five participants are representative of the target population of the study: adult learners of an L2 for academic purposes. They learned English for academic purposes and they were at least intermediate English learners. This is important because the target adult learners of an L2 for academic purposes program are mostly at least intermediate level language learners. Additionally, they have different first languages: Chinese and Arabic. The adult L2 or FL learners for academic purposes have a diversity of first languages. L1 has a strong influence on the difficulty or the ease of learning the vocabulary of their L2 or FL (Hamada & Koda, 2008; Laufer, 1997; Liu & Todd, 2014; Swan, 1997). Moreover, the disciplines that the participants are engaged in mostly did not overlap with those of the reading materials: Geology, Biology, Film Studies, and Anatomy. This was to ensure the ecological validity of this study. Usually people read academic texts to understand and learn something new. However, research also shows that for adequate reading comprehension, readers need sufficient background knowledge of the content of texts (Pulido, 2003; Carrell & Eisterhold, 1983; Carrell, 1983; Hudson, 1982; Pulido & Hambrick, 2008). Thus, in normal academic reading, readers are expected to read academic texts at an appropriate academic level for them. Since the reading materials in this study are all introductory materials, to make the texts not too easy nor too hard for them to understand, people whose disciplines overlap with the reading materials were not allowed to participant.

3.2 Materials

This section describes the reading materials of the study. Four texts were selected as reading texts. These four texts are segments from the textbooks of introductory courses across universities in North America. Table 3, Table 4, Table 5, and Table 6 list the source information of the selected texts.

All the texts are from the first chapters of the source textbooks. There is little prerequisite knowledge required to understand the first chapters of the textbooks of the introductory courses. Therefore, they are appropriate for the 5 participants whose disciplines did not overlap with the texts. The textbooks are required for university students in North America so they are representative of authentic English academic texts. The length of each of the reading materials range from 3000 running words to 4000 running words. The technical words in the texts are contained in different types of contexts such as pictures, examples, and vague or clear descriptions.

As suggested by the titles of the source textbooks, the four texts are from four disciplines: geology, biology, anatomy, and film study. To make this study generalizable to academic reading of as many disciplines as possible, the reading materials were chosen from multiple disciplines. The proportions of technical vocabulary in academic texts from different disciplines vary to a large extent (Chung and Nation, 2003). Readers need to know most of the words in a text to get an adequate comprehension (Nation, 2013; Nation, 2006; Hu and Nation, 2000; Liu and Nation, 1985). Technical words are uncommon in general language and it is highly possible that they are not known by the participants. The contexts with more technical words therefore may be less informative to readers. Less informative contexts negatively influence the correct guessing of the target words' meanings and the incidental learning of these words (Webb, 2007, 2008; Beck et al, 1983; Nagy et al, 1987). From this perspective, the variation of the proportion of technical vocabulary may affect the efficiency of incidental learning of the target words through RR of academic texts. Thus, it is possible that the level of difficulty of incidental learning of technical vocabulary varies from discipline to discipline.

These reading materials meet the following criteria:

1. They are authentic English academic texts that EAP students could encounter in academic life;
2. They are from the 1st chapters of introductory textbooks from different disciplines so they are appropriate materials for the 5 participants who are not from these four disciplines;
3. They are from different disciplines so they are representative of academic texts from multiple disciplines.

The lexical profiles of all four reading materials were measured. The "Compleat Lexical Tutor" which is available at http://www.lextutor.ca/vp/comp/ was used to determine the lexical profiles based on the BNC/COCA word lists (Nation, 2012) and the Academic Word List (Coxhead, 2000). Table 7 presents a summary of lexical profiles of the texts. All four texts chosen include a large proportion of technical vocabulary. The proportion of technical vocabulary in the chosen texts range from 15.39% to 23.37%. The anatomy text among the four has the most technical vocabulary. There is one technical word in every 4 to 5 running words in the anatomy text. The biology text has the least technical words. There is one technical word in every 6 to 7 running words in this text.

Table 3 Source information of the geology text

Source textbook	*Physical Geology* (https://opentextbc.ca/geology/)
Authors or editors of the textbook and publication year	Earle, 2015
Source chapter in the textbook	Chapter 1 (page 2-14 of the original book)
Course code and name requiring the textbook	EOSC 110 (The Solid Earth: A Dynamic Planet)
Year of the course	Winter semester of the 2016-2017 academic year
Online source of course outline	https://www.eoas.ubc.ca/courses/eosc110/eosc110.htm
The department offering the course	Department of Earth, Ocean and Atmospheric Sciences
University offering the course	University of British Columbia

Table 4 Source information of the biology text

Source textbook	*Biology: Exploring the diversity of life (2nd Canadian Ed.)*
Authors or editors of the textbook and publication year	Russell, 2010
Source chapter in the textbook	Chapter 1 (Page 1-9 of the original book)
Course code and name requiring the textbook	Biology 1001A (Biology for Sciences I)
Year of the course	Fall semester of the 2014-2015 academic year
Online source of course outline	https://www.uwo.ca/biology/pdf/undergraduate/Biology%201001A%202014.pdf
The department offering the course	Department of Biology
University offering the course	University of Western Ontario

Table 5 Source information of the film studies text

Source textbook	*Film Art: An Introduction (11th edition)*
Authors or editors of the textbook and publication year	Bordwell & Thompson, 2013
Source chapter in the textbook	Chapter 1 (Page 9-17 of the original book)
Course code and name requiring the textbook	FMS 20/FAH 0092 (Art of the Moving Image)
Year of the course	Fall semester of the 2016-2017 academic year
Online source of course outline	https://ase.tufts.edu/art/courses/syllabi/fall2016/FAH_92_05_F16.pdf
The department offering the course	School of Arts and Sciences, Department of Film and Media Studies
University offering the course	Tufts University

Table 6 Source information of the anatomy text

Source textbook	*Human Anatomy (4th ed.)*
Authors or editors of the textbook and publication year	M. McKinley et al, 2014
Source chapter in the textbook	Chapter 1 (Page 1-10 of the original book)
Course code and name requiring the textbook	ANAT 100 (Anatomy of the Human Body)
Year of the course	Throughout the 2016-2017 academic year
Online source of course outline	http://www.queensu.ca/artsci_online/courses/anatomy-of-the-human-body
The department offering the course	Department of Biomedical and Molecular Sciences
University offering the course	Queen's University

Table 7 A summary of lexical coverage of the materials

Categories of vocabulary based on their frequency	Number of words / Lexical coverage of words	Geology	Biology	Anatomy	Film Studies
High-frequency words (The 1st most frequent 2000 word families from the BNC corpus and the COCA corpus)	N	2667	2572	2884	3017
	Lexical coverage	81.46%	76.43%	73.11%	79.56%
Mid frequency words (The words from the 3rd to the 9th 1000 word family lists from the BNC corpus and the COCA corpus)	N	415	554	808	512
	Lexical coverage	13.19%	16.46%	20.48%	13.50%
Low-frequency words	N	40	100	57	54
	Lexical coverage	1.18%	2.21%	2.22%	1.43%
Off-list words	N	133	165	166	209
	Lexical coverage	4.19%	4.90%	4.21%	5.51%
Academic words	N	207	284	377	331
	Lexical coverage	6.30%	8.44%	9.56%	8.73%
Technical vocabulary*	N	534	518	922	616
	Lexical coverage	16.25%	15.39%	23.37%	16.52%
In total	N	3286	3365	3945	3792
	Lexical coverage	100%	100%	100%	100%

*: The technical vocabulary in texts here contains both single word technical vocabulary and multiple word technical vocabulary.

To measure the proportion of technical vocabulary in each text, it is necessary to first identify the technical vocabulary in them. The technical vocabulary in the texts was identified based on four 4-point rating scales. Every discipline has a separate rating scale. The rating scales for the geology text, the biology text, and the film studies text were developed from two models designed by Chung and Nation (2003). The rating scale for the anatomy text was directly adopted from the one designed by Chung and Nation (2003). Deciding whether meanings of individual words fall into the knowledge system of a certain discipline was involved when developing the rating scales to identify the technical vocabulary (Chung and Nation, 2003). Words classified at point 3 and point 4 categories in the rating scales were identified as technical vocabulary. The scales range from the most irrelevant (point 1) to the most relevant (point 4) points.

For example, based on the rating scale for biology texts, “incoming” has nothing to do with the biology field. It therefore was classified as a point 1 category item. Thus, it is not a technical word of biology. In contrast, “photosynthesis” is a common topic in biology and it rarely appears outside the field of biology. Thus, it was classified as a point 4 category item. It is therefore a technical word of biology. Table 8, Table 9, Table 10, and Table 11 illustrate the four rating scales.

Table 8 A rating scale for determining technical words in geology texts.

Point 1	Words or collocations, such as function words, whose meanings have no particular relationship with the field of geology or any other fields belong to this category. Words in this category are independent of the subject matter. Examples are: *and, what, it, many, result, here, these, understand, aspect, become, indeed, case, important, answer, common, commonly, for example, change, textbook.*
Point 2	Words or collocations whose meanings are minimally related to the field of geology belong to this category. They describe the positions, process, movements, or features, functions of the earth science. Examples are: *study, assessment, laboratory, fieldwork, proportion, dimension, structure, compose, bury, mixture, experiment.*
Point 3	Words or collocations whose meanings are closely related to the field of geology belong to this category. They refer to parts, structures or functions, features and theories of the geology, such as the regions of the Earth, systems of the Earth, nature of the systems of the Earth. Such words are also used in general language. In addition, such words are also used in general language. Words in this category may be technical terms in a specific field like psychology and yet may occur with the same meaning in general language. Examples are: *mineral, rock, river, Earth, universe, geology, geologist, sand, mud, climate, storm, star, earthquake, soil, water, resource, nature, environment, stream bed, location.*
Point 4	Words or collocations whose meanings are specific to the field of geology and are not likely to be known in general language belong to this category. They refer to structures, functions and features of the Earth science systems or parts. These words have clear restrictions of usage in geology. Examples are: *cobble, slope failure, geological time, granite, magma, sandstone, schist, planate tectonics, asthenosphere.* It's common to use the knowledge of biology, chemistry and physics to explain geological theories and phenomena. Thus, the technical words common in biology, chemistry and physics closely related to geology are also included in this category. Examples are: *halite, sodium, chlorine, lattice, carbon, oxygen.*

Note: this table was developed based on the rating scales designed by Chung and Nation (2003, p. 105)

Table 9 A rating scale for determining technical words in biology texts.

Point 1	Words or collocations, such as function words, whose meanings have no particular relationship with the field of biology and any other fields close to biology belong to this category. Words in this category are independent of the subject matter. Examples are: *and, why, it, many, well-known, small, instead of, so that, for example, change, first, most, both, use, make up, chapter, textbook.*
Point 2	Words or collocations whose meanings are minimally related to the field of biology belong to this category. They describe the positions, movements, or features, functions of the biological principles or organisms. Examples are: *scientific, revolution, introductory, portion, define, function, serve, include, contain, nature, physical, mass, property, experiment.*
Point 3	Words or collocations whose meanings are closely related to the field of biology belong to this category. They refer to parts, structures or functions, features and theories of the biology, such as the regions of different organisms, systems of the biological field, nature of the systems of biological field and organisms. In addition, such words are also used in general language. Words in this category may be technical terms in a specific field like biology and yet may occur with the same meaning in general language. The words common in other fields closely related to biology are also included. Examples are: *light, energy, wavelength, environment, life, eyes, absorb, wave, plant, vision, water, species, cell.*
Point 4	Words that have a meaning specific to the field of biology and are not likely to be known in general language belong to this category. They refer to structures, functions and features of the biological systems or organisms. These words have clear restrictions of usage in biology. Examples are: *pigment, genus, organism, microbe, archaea, halobacterium, etc.* It's common to use the knowledge of chemistry and physics to explain biological theories and phenomena. Thus, the technical words common in chemistry and physics closely related to biology are also included in this category. Examples are: *carbon dioxide, oxygen, electron, atom, concentration, carbon bound, photon, enzyme.*

Note: this table was developed based on the rating scales designed by Chung and Nation (2003, p. 105)

Table 10 A rating scale for determining technical words in film studies texts.

Point 1	Words or collocations, such as function words, whose meanings have no particular relationship with the field of film studies belong to this category. Words in this category should also have no particular relationship with any other disciplines that are relative to film studies. Words in this category are independent of the subject matter. Examples are: *and, why, it, many, rely on, small, instead of, so that, for example, change, first, most, both, use, make up, anyone, textbook.*
Point 2	Words or collocations whose meanings are minimally related to the field of film studies belong to this category. They describe the positions, movements, or features, functions of the theories in film studies or the technologies to make films. Examples are: *consist of, separate, tendency, still, slide, static, ribbon, rate, machine.*
Point 3	Words or collocations whose meanings are closely related to the field of film studies belong to this category. They refer to parts, structures or functions, features of technologies to make films or theories of film studies. For instance, the names of the parts or structures of machines to make films and the names and contents of the theories of film studies may be in this category. In addition, such words are also used in general language. Words in this category may be technical terms in a specific field like film studies and yet may occur with the same meaning in general language. The words common in other fields closely related to film studies are also included. Examples are: *light, image, positive, negative, unexposed, film, chemical, dye, dark, sound, shutter, theater, production, tape, picture, camera, lens, shoot, strip, video, television.*
Point 4	Words or collocations whose meanings are specific to the field of film studies and are not likely to be known in general language belong to this category. They refer to structures, functions and features of machines or technologies to make films or theories of film arts. These words have very low frequency outside the field of film studies. Examples are: *pixel, resolution, digital motion picture camera, diode, gauge, projector, fps (frames per second), emulsion, sprocket, Imax system, magnetic track, optical sound track, variable area, monophonic, stereophonic, megapixel.* It's common to use the knowledge of optics, physics and chemistry to explain the principles or phenomena of film studies. Thus, the technical words common in chemistry and physics closely related to film studies are also included in this category. Examples are: *magnetic, aperture.*

Note: this table was developed based on the rating scales designed by Chung and Nation (2003, p. 105)

Table 11 A rating scale for determining technical words in anatomy texts (Chung and Nation, 2003, p.105)

Point 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, 12, adjacent, amounts, common, commonly, directly, constantly, early,* and *especially*.
Point 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, lodges, protects*.
Point 3	Words that have a meaning that is closely related to the field of anatomy. They refer to parts, structures or functions of the body, such as the region of the body and systems of the body. Such words are also used in general language. The words may have some restrictions of usage depending on the subject field. Examples are: *chest, trunk, neck, abdomen, ribs, breast, cage, cavity, shoulder, gridle, skin, muscles, wall, heart, lungs, organs, liver, bony, abdominal, breathing*. Words in this category may be technical terms in specific field like anatomy and yet may occur with the same meaning in other fields and not be technical terms in those fields.
Point 4	Words that have a meaning specific to the field of anatomy and are not likely to be known in general language. They refer to structures and functions of the body. These words have clear restrictions of usage depending on the subject field. Examples are: *thorax, sternum, costal, vertebrae, pectoral, fascia, trachea, mammary, periosteum, hematopoietic, pectoralis, viscera, intervertebral, demifacets, pedicle*.

Note: This table is adopted from Chung and Nation, 2003, p. 105).

3.3 The target items

The target items were randomly selected from the technical words classified at point-4 on the scales to ensure that they were technical items. Seventy-six target items were selected from the four texts. Each text has approximately twenty target items. Some target items appear in figures or tables in texts while others do not. The informativeness of contexts containing the target items vary. The target items are presented in Table 12.

Table 12 The target words from four texts

The texts containing the target words	The target words	The number of target words
Geology text	*lattice, convection, igneous rock, sedimentary rock, metamorphic rock, plate tectonics, mantle, asthenosphere, lithosphere, geothermal gradient, granite, magnesium, basalt, subduct, convergent boundary, mega annum, halite, Phanerozoic, weather, schist.*	20
Biology text	*particle-wave duality, photon, pigment, cellular respiration, conjugated system, photosynthesis, biosphere, carbohydrate, cataracts, ophthalmologist, electromagnetic radiation, eyespot, chloroplast, photoreceptor, retinal, Halobacterium, opsin, rhodopsin, phytochrome, algae.*	19
The text of film studies	*perforation, aperture, reel, emulsion, sprocket, gauge, optical, pixel, resolution, flicker, celluloid, gelatin, pulsation, historical spectacles, monophonic, stereophonic, sensor, speck, encrypt.*	19
Anatomy text	*etching, cadaver, plastination, physiology, microscopic anatomy, gross anatomy, cytology, histology, embryology, Embryology, Pathologic anatomy, Radiographic anatomy, epithelial tissue, metabolism, homeostasis, skeletal system, integumentary system, cardiovascular system, urinary, small intestine*.	18

Two factors influencing the incidental learning of L2 vocabulary, namely frequency of occurrence and pictorial annotations were also investigated in this study. The frequency of occurrence of the target words within reading materials and pictorial contexts containing the target words were also determined. The textual contexts containing target items were also examined in order to further describe the target items. This data can be found in the Appendices.

The textual and pictorial contexts were evaluated based on two rating scales. Both of the rating scales are based on the context rating scale originally designed by Webb (2007, 2008) and Beck et al (1983). The rating scale for pictorial contexts was designed according to how informative the pictorial contexts are for readers to understand the target items in the pictures. The pictorial contexts include all the notes, the pictures and the other texts in figures or tables. In the pictorial rating scale, from point 1 to point 3 the informativeness of the pictures, the figures, or the tables increases. Point 1 figures or tables have no clues about the meanings of the target items contained. For example, the note in *Figure 1.5* (Figure 1 of this paper) in the biology text provides minimal indication of the meaning of *algae* ("***Figure 1.5*** *Structure of some common pigments...Phycoerythrobilin, red photosynthetic pigment found in red algae...*"). Point 3 figures or tables explicitly illustrate the meanings of the target words. For example, the picture and the note in the *Figure 1.1* (see Figure 2 of this paper) in the biology text explicitly indicate the meaning of *eyespot* in terms of what it looks like, where it is, and how it functions ("***Figure 1.1*** *Chlamydomonas reinhardtii. Each cell contains a single chloroplast used for photosynthesis as well as an eyespot for sensing light in the environment.*"). Table 13 illustrates the rating scale for the pictorial contexts.

Figure 1 Figure 1.5 of the biology text from the book Biology: Exploring the diversity of life (Russell, 2013, p. 5).

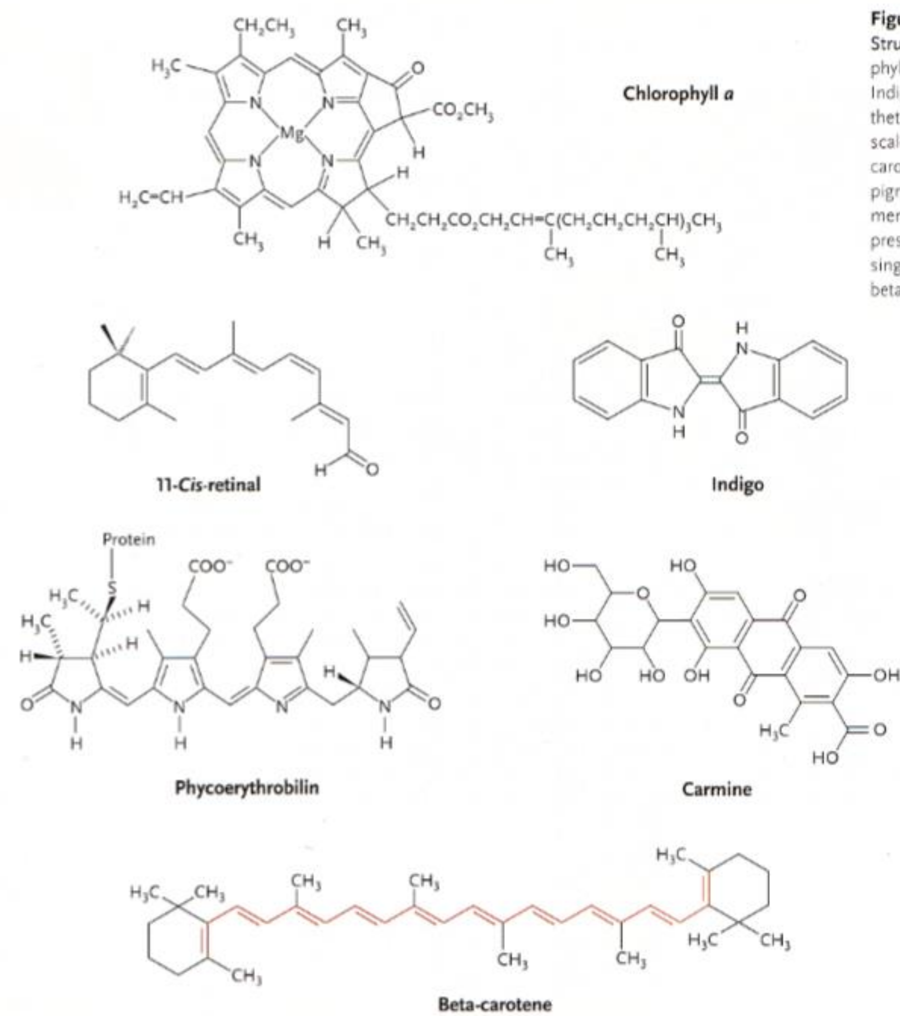


Figure 1.5
Structure of some common pigments. Chlorophyll *a*, photosynthesis. 11-*Cis*-retinal, vision. Indigo, dye. Phycoerythrobilin, red photosynthetic pigment found in red algae. Carmine, scale pigment found in some insects. Beta-carotene, an orange accessory photosynthetic pigment. A common feature of all these pigments that is critical for light absorption is the presence of a conjugated system of double/single carbon bonds (shown in red for beta-carotene).

Figure 2 Figure 1.1 of the biology text from the book Biology: Exploring the diversity of life (Russell, 2013, p. 2).

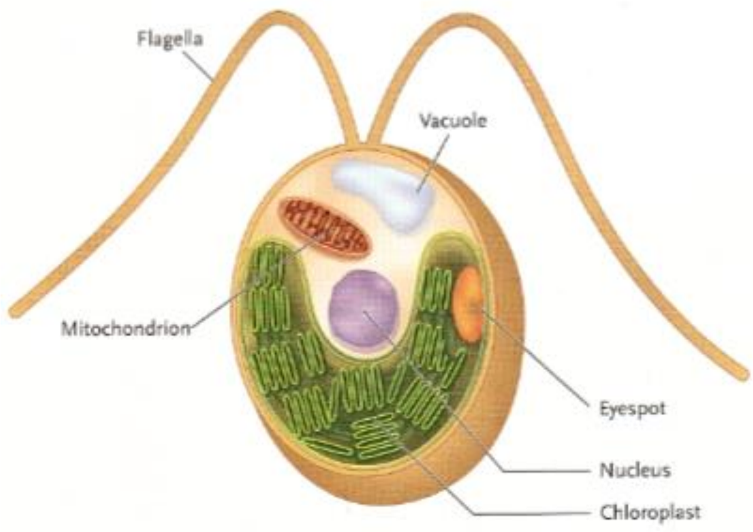


Figure 1.1
Chlamydomonas reinhardtii. Each cell contains a single chloroplast used for photosynthesis as well as an eyespot for sensing light in the environment.

Table 13 A rating scale for evaluating the informativeness of the pictorial contexts containing the target words

Point 1	The pictures and their captions are not helpful for the understanding of the target words.
Point 2	It is almost impossible that the exact meaning of the target words can be understood through the pictures. However, information in the pictures may lead to partial knowledge of the target word’s meaning.
Point 3	The target words are clearly illustrated in the pictures. From the pictures readers have a good chance to understand the concepts of the target words. They can understand the positions, shapes and functions of the concepts behind the forms of target words through the pictures.

Note: A pictorial context includes the notes, the pictures and the other texts in figures or tables.

The rating scale for evaluating the textual contexts was designed in relation to the extent that readers may be able to correctly guess the word meanings. The textual contexts in this study are the exact sentences containing the target items or the two or three sentences around the target items. In the textual context rating scale, from point 1 to point 4, the informativeness of the contexts is increasing. Table 14 illustrates the textual context rating scale. Table 15 presents some examples of the contexts of different points. Every context containing target items was evaluated. The frequency of the target items in both textual contexts and the pictorial contexts was recorded. The detailed description of the target words and the contexts containing them is available in the Appendix.

Table 14 A rating scale for evaluating the informativeness of the textual contexts containing the target words

Point 1	The target word is almost impossible to be guessed correctly. The text contains no directional contextual clues.
Point 2	Information in the context may lead to partial but very limited knowledge of the target word's meaning. For example, whether the target word is positive, negative or neutral could be inferred from its context.
Point 3	It's hard to guess the meaning of the target word from the context. However, it is possible to partially understand the meaning of the target word. There is still uncertainty of the exact meaning of the word.
Point 4	It is possible that the meaning of the target word can be guessed correctly from the context. The clear, direct definition of the target word may be given, and there are few meanings that are logical apart from the correct meaning in context.

Note: A context is one or two sentences containing a target word. (Webb, 2007, 2008, Beck et al., 1983)

Table 15 Examples of textual contexts of different points

Target items	Points of contexts	Contexts
sedimentary rock	Point 1	Metamorphic rocks form when either igneous or sedimentary rocks are heated and squeezed to the point where some of their minerals are unstable and new minerals form to create a different type of rock.
granite	Point 2	Although a hand-sized piece of granite may have thousands of individual mineral crystals in it, there are typically only a few different minerals, as shown here.
	Point 3	Examples of rocks are granite, basalt, sandstone, limestone, and schist.
	Point 4	Igneous rocks form from magma (molten rock) that has either cooled slowly underground (e.g. to produce granite) or cooled quickly at the surface after a volcanic eruption (e.g. basalt).

3.4 The Measures

Four measurements were used in the present study:

1) UVLT (New Vocabulary Levels Test) (Webb, Sasao, & Ballance, 2017);

2) Dictation test measuring productive knowledge of written form;

3) The form-meaning connection interview respectively;

4) reading speed test.

The UVLT was used for selecting the participants and describing the participants' language proficiency. Vocabulary knowledge is an important aspect in language learning, thus it is an important predictor of language learners' language proficiency. L2 learners should consider learning an L2 for academic purposes at least after they have mastered the high-frequency words (Nation, 2013). Thus, the UVLT was introduced to potential participants to measure whether they had mastered the 2000 high-frequency word families. Those having low scores on the most high-frequency words were excluded.

The following two measurements were used to measure the vocabulary gains and retention from the repeated reading treatment. They were used in the pre-test, the post-test, and the delayed post-test. During the test sessions, the dictation test was presented first then the interview test followed. The order of the two tests was carefully considered to avoid test learning effects from taking the prior test. The reading speed measurement was only for distracting the participants from the vocabulary learning focus of the study. This instrument was used during the whole repeated reading treatment. The last 3 tests are to be introduced in detail.

Dictation test measuring productive knowledge of written form. In this test the participants were asked to write down the target items on a piece of blank paper provided by the researcher after hearing the pronunciation of the items. *Google Translate* was used to provide the pronunciations of the target items. For example, after hearing the word *perforation* read by *Google Translate*, the participants were asked to write *perforation* down on the paper provided. The aim of this test was to measure whether the participants could correctly spell the target items.

Only completely correct spellings were marked as correct. For example, to have their answer for the target item *plastination* marked as correct in this test, the participants' writing of *plastination* had to be exactly correct; minor mistakes in spelling were unacceptable. The target population as well as the participants of the study are advanced or intermediate language learners. It is therefore highly possible that they are familiar with the word building rules of English which might help them to partially correctly spell the items as they hear them. Thus, if partial knowledge of written forms of the target items had been also considered, it would have been hard to interpret whether the correct spellings resulted from accumulated linguistic knowledge or from vocabulary learning from the RR treatment.

The form-meaning connection interview. the participants were interviewed to measure their receptive form-meaning connection knowledge of the target items. The participants were asked to provide any information they knew about the meaning senses that they encountered in the reading materials. The items' written forms were shown to the participants in this test. In addition, during the progress of the interview, the researcher provided prompts such as: *That's part of it, can you make it clearer* or *What does that (point to a vague example or definition provided by the participant) mean* if participants only provided partial knowledge or incorrect answers. If the participants really could not recall the full correct answer, the researcher provided prompt words designed previously to them. These prompt words are the words with concepts relevant to the target items, but they do not cover the full correct answers and they might cover one of the aspects of correct answers. For example, the prompt answer of the word *photosynthesis* is *light*.

Here is an example of the interview test for the word *photosynthesis*:

Researcher: Do you know the meaning of photosynthesis? You can tell me anything you know about its meaning, or functions, or whatever you read in the text about photosynthesis. You can tell me a definition, or give me an example, or you can even draw a picture to show me (if an unclear meaning is provided, go to the next question)→That's part of it, can you make it more clear? (with an unclear definition or example or picture, go to the next question) →What does that (point to a vague example or definition provided by the participant) mean? → Whether "light" reminds you of anything about "photosynthesis"?

Correct answer: *It is the process (aspect No. 1) by which green plants and some other organisms (aspect No.2) use sunlight (aspect No. 3) to synthesize nutrients (aspect No. 4) from carbon dioxide and water (aspect No.5). Photosynthesis in plants generally involves the green pigment chlorophyll (aspect No. 6) and generates oxygen as a by-product (aspect No. 7).*

This interview is a combination of the interviews developed by Schmitt (1998, 1999) and Nagy et al. (1985). All the interviews were conducted in a one-on-one manner and to ensure the precision of the data, the interviews were recorded. The exact model answers of the target items had been designed for the scoring of this test. Each model answer for each target item includes numerous aspects of the meaning of the words. The models and the scoring system of the test are to be introduced in detail in the following subsection.

The model answers of every target item cover diverse aspects such as definition, functions, and locations. All these aspects are used or introduced in the reading materials. It was not reasonable to expect the participants to know the meaning or knowledge of a target item that was not encountered in the reading materials. However, it is important to note that different target words include different numbers of aspects of meaning. For example, the word "pixel" has 4 aspects (a, *a short for "picture elements"*; b, *they are small glowing dots*; c, *they make up the image of a picture*; d, *the density of visual information increases proportionately with the number of pixels*). In contrast, the word "emulsion" only has 2 aspects (a, *it is a layer of substances on photographic film*; b, *it contains chemicals which are sensitive to light*).

To define each target item so that the model answers of this test could be as precise as possible, the glossaries of the textbooks containing the reading materials, three online learner's dictionaries (Cambridge Learner's Dictionary at http://dictionary.cambridge.org/dictionary/learner-english/, Oxford Learner's Dictionary at http://dictionary.cambridge.org/dictionary/learner-english/, and Merriam Webster Learner's Dictionary at http://www.learnersdictionary.com/) , and the definitions of the target items from Wikipedia were consulted. The definitions in the glossaries of the target words were preferred the most, followed by the definitions in the learner's dictionaries. The definitions from Wikipedia were preferred the least. Since the target items should be defined technically, the technical glossary provided by experts of different disciplines (the writers or the editors of the textbooks) should be reliable. Chung and Nation (2003, 2004) suggested that consulting experts of a discipline is a reliable method to identify technical vocabulary. However, not all the target items have definitions in the glossaries attached to the textbooks. Other resources such as dictionaries are needed for defining the target items. Schmitt (2010) suggested that the vocabulary used in the models of the correct answers of this interview should be mostly high-frequency words. The words used in definitions of items in learner's dictionaries usually are more frequent than those in other dictionaries. Thus, the definitions of the target words in the learner's dictionaries were also preferred. However, the three learners' dictionaries still miss definitions of some target items, especially for multi-word items. The definitions of these items are from Wikipedia. Only when the meaning senses and aspects from the sources described above overlap with those introduced in the reading materials, they were used as models of correct answers of this test. For example, the correct answer for the item **photon** is: *It is a type of energy particles (aspect No. 1); light is composed of a stream of photons (aspect No. 2).*

The participants got one of three scores for each target item in the interview test: score 0, 1, or 0.5. This three-point rating scale was developed from various previous studies (Pigada & Schmitt, 2006; Pellicer-Sánchez & Schmitt, 2010; Schmitt, 1998; 1999). To get point 1, the answers provided by participants must cover all the aspects. To get point 0.5, the participants only needed to provide at least one aspect included in the full correct answers. Point 0 indicated that the participants gained no knowledge of a target item.

This paragraph describes the last measurement: a reading speed test. The objective of this test was just to distract the participants from the aims of the study and to motivate the participants for their consistency. Thus, the results of the test were not taken in to consideration in data analysis. The participants were asked to record the time that they use to finish reading the texts in each RR session. They had a stop watch to record their reading time. Their reading time were measured by the WPM. Increase or decrease of reading speed across the reading sessions were reported to the participants at the beginning of the following reading session.

3.5 The Procedure

This study was conducted in a pre-test, RR treatment, post-test, and delayed post-test design. The five participants received the treatment and took the tests individually with the researcher. The participants were informed that the purpose of the study was to investigate the effect of RR of academic texts on academic reading efficiency. They were also informed that by the end of the reading treatment there would be a reading comprehension test and that their reading time in each RR session would be recorded for measuring their reading speed. The participants took the UVLT (Webb, Sasao, & Ballance, 2017), the dictation test measuring productive knowledge of written form, and the form-meaning connection interviews during the two pre-test sessions individually one week prior to the start of the RR treatment. During the treatment, 10 reading sessions were conducted for each participant. In each session, every participant read one text one time and the time they used for finishing the reading was recorded. During the whole treatment, each participant read each text either once, twice, three times, or four times. Thus, after the treatment, every text was read once, twice, three times, and four times by different participants; every participant had read one text one time, another text twice, the third text three times, and the last text four times.

To prevent the participants from guessing the aims of the study correctly, the post-test sessions and delayed post-test sessions were conducted after the whole reading treatment. During each test session, a surprising dictation test was presented to the participants first. Then the *form-meaning connection interview* was conducted in the name of a reading comprehension test. The delayed post-tests were conducted one week after the post-tests. The instruments in the delayed post-tests were the exact same in the post-tests with the same presenting order. Considering that the interview test was time consuming, the pre-tests, the post-tests, and the delayed post-tests measuring target items from different texts were presented text by text. Table 16 to Table 19 describe the procedure of the whole experiment and each table is a schedule for each participant.

3.5.1 The procedure of the reading treatment

One week after the UVLT test and the pre-tests, the reading treatment began. Each participant took 10 reading sessions. Each session lasted approximately for one hour. The schedule of the reading sessions for each participant is presented in Table 16, Table 17, Table 18, and Table 19. At the beginning of each reading session, a copy of one assigned text of that session was provided to each participant and they started the silent reading of the text. Participants were encouraged to try their best to understand the text. Even though each participant was told they would have one hour to finish reading, there was no time limitation for reading time. In addition, the participants were also informed that they did not have to completely understand all the content of the texts by the end of each session or by the end of the whole reading treatment but that they needed to try their best to comprehend. Considering the aim of incidental learning of technical vocabulary through RR, to avoid intentional learning, the participants were not allowed to use dictionary or other resources except for the reading materials during the reading sessions. During their silent reading process, the participants were asked to record their reading time. A stop watch was used to measure the reading time. The reading texts were collected at the end of each RR session by the researcher to ensure the participants did not have extra access to the target words out of the reading sessions. By the end of reading sessions, the participants were required to report their reading time.

Table 16 The procedure for participant 1.

Week/day	Mon	Tue	Wed	Thu
Week 1	Pre-test and UVLT	Pre-test		
Week 2	Geology text			
Week 3	Geology text	Biology text		
Week 4	Geology text	Biology text	Film Studies text	
Week 5	Geology text	Biology text	Film Studies text	Anatomy text
Week 6	Post-test Geology	Post-test Biology	Post-test Film Studies	Post-test Anatomy
Week 7	Delayed post-test Geology	Delayed post-test Biology	Delayed post-test Film Studies	Delayed post-test Anatomy

Table 17 The procedure for the participant 2.

Week/day	Mon	Tue	Wed	Thu
Week 1	Pre-test and UVLT	Pre-test		
Week 2	Film Studies text			
Week 3	Film Studies text	Anatomy text		
Week 4	Film Studies text	Anatomy text	Geology text	
Week 5	Film Studies text	Anatomy text	Geology text	Biology text
Week 6	Post-test Film Studies	Post-test Anatomy	Post-test Geology	Post-test Biology
Week 7	Delayed post-test Film Studies	Delayed post-test Anatomy	Delayed post-test Geology	Delayed post-test Biology

Table 18 The procedure for the participant 3.

Week/day	Mon	Tue	Wed	Thu
Week 1	Pre-test and UVLT	Pre-test		
Week 2	Biology text			
Week 3	Biology text	Geology text		
Week 4	Biology text	Geology text	Anatomy text	
Week 5	Biology text	Geology text	Anatomy text	Film Studies text
Week 6	Post-test Biology	Post-test Geology	Post-test Anatomy	Post-test Film Studies
Week 7	Delayed post-test Biology	Delayed post-test Geology	Delayed post-test Anatomy	Delayed post-test Film Studies

Table 19 The procedure for the participant 4.

Week/day	Mon	Tue	Wed	Thu
Week 1	Pre-test and UVLT	Pre-test		
Week 2	Anatomy text			
Week 3	Anatomy text	Film Studies text		
Week 4	Anatomy text	Film Studies text	Biology text	
Week 5	Anatomy text	Film Studies text	Biology text	Geology text
Week 6	Post-test Anatomy	Post-test Film Studies	Post-test Biology	Post-test Geology
Week 7	Delayed post-test Anatomy	Delayed post-test Film Studies	Delayed post-test Biology	Delayed post-test Geology

Table 20 The procedure for the participant 5.

Week/day	Mon	Tue	Wed	Thu
Week 1	Pre-test and UVLT	Pre-test		
Week 2	Anatomy text			
Week 3	Anatomy text	Film Studies text		
Week 4	Anatomy text	Film Studies text	Biology text	
Week 5	Anatomy text	Film Studies text	Biology text	Geology text
Week 6	Post-test Anatomy	Post-test Film Studies	Post-test Biology	Post-test Geology
Week 7	Delayed post-test Anatomy	Delayed post-test Film Studies	Delayed post-test Biology	Delayed post-test Geology

4 Results and Analysis

4.1 Do adult L2 learners for academic purposes incidentally learn L2 technical vocabulary in academic texts through repeated reading?

To understand to what extent L2 technical vocabulary could be learned incidentally through repeated reading of academic texts, the descriptive statistics of the vocabulary gains were calculated; the vocabulary knowledge gains were also compared in a within-subject manner and a within-text/cross-subject manner. The pre-tests (see Table 22) have shown that the participants were very different in their knowledge of the target items. Previous studies have shown that relative gains are more accurate in comparing vocabulary knowledge gains between participants when participants vary at their potential gains (Webb and Chang, 2015; Horst et al, 1998). Thus, both raw gains and relative gains were calculated. Here are the formulas used to calculate the relative gains and relative retentions (Webb and Chang, 2015; Horst et al, 1998):

(1). for relative gains:

$$\frac{delayed\ post\ test\ raw\ score - pre\ test\ score}{total\ scores - pre\ test\ score} \text{ X } 100\%$$

(2). for relative retention:

$$\frac{delayed\ post\ test\ raw\ score - pre\ test\ score}{total\ scores - pre\ test\ score} \text{ X } 100\%$$

4.1.1 Descriptive Statistics

Descriptive statistics of the gains in both receptive knowledge of form-meaning connection and productive knowledge of written form on post-tests and delayed post-tests are presented in Table 21. Independent t-tests were conducted to determine whether any of the changes of the mean vocabulary gains were statistically significant. As expected, due to the small sample size (Muijs, 2011), no statistical significant changes in mean vocabulary knowledge gains (for both the gains in receptive knowledge of form-meaning connection and productive knowledge of written form) were found. Therefore, all the changes in mean vocabulary knowledge gains discussed in the following sections are numerical changes rather than statistically significant changes.

Table 21 Means of relative gains of incidental vocabulary knowledge (N=5)

The number of reading of texts	Gains in receptive knowledge of form-meaning connection				Gains in productive knowledge of written form			
	Means of post-test relative gains	SD	Means of delayed post-test relative gains	SD	Means of post-test relative gains	SD	Means of delayed post-test relative gains	SD
1 time	**15.95%**	9.59%	14.13%	8.81%	**35.38%**	28.53%	40.67%	28.04%
2 times	**14.62%**	20.16%	13.22%	18.84%	**24.64%**	24.58%	40.74%	18.74%
3 times	**21.83%**	14.28%	23.60%	15.36%	**35.40%**	9.89%	46.19%	20.08%
4 times	**27.56%**	21.24%	29.02%	14.36%	**41.25%**	32.36%	51.67%	26.66%

4.1.1.1 The mean gains in receptive knowledge of form-meaning connection.

For the incidental learning of receptive knowledge of form-meaning connection, as the number of readings increases, the mean relative gains tend to increase consistently. The data on post-tests in Table 21 indicates that after reading the texts one time, the mean relative gains of the five participants were 15.68%. This number decreased slightly to 14.62% after reading the texts twice (p=0.897). After reading 3 times, the mean gains increased to 21.83% (p=0.488). After reading 4 times, the mean gains increased to 27.56% (p=0.662). The mean gains on delayed post-tests were 14.13%, 13.22%, 23.60%, and 29.02% after reading the texts one, two, three, and four times, respectively.

4.1.1.2 The mean gains in productive knowledge of written form

The results also show that the mean relative gains in productive knowledge of written form increased consistently from reading 2 to 4 times. However, from reading 1 to 2 times, the mean relative gains sharply decrease. Table 21 shows that from pre-tests to post-tests, the mean relative gains in productive knowledge of written form decreased from 35.38% after reading one time to 24.64% after reading twice (p=0.588). The gains increased to 35.40% after reading three times (p=0.390), and after reading 4 times, the gains further increased to 41.25% (p=0.777). From pre-tests to delayed post-tests, the mean relative gains in productive knowledge of written forms are 40.67%, 40.70%, 46.19%, and 51.67% after reading 1, 2, 3, and 4 times, respectively.

The vocabulary gains in post-tests and delayed post-tests were compared to examine whether learning effects occurred on the delayed post-test. Six out of 8 sets of comparisons (see Table 21) show that the gains on the delayed post-tests are larger than those in the post-tests. This increase of vocabulary knowledge gains from post-tests to delayed post-tests indicates that a learning effect occurred through taking the earlier test. Since the results from the delayed post-tests cannot be attributed solely to the repeated reading, the results on the delayed post-tests will not be discussed further.

4.1.2 Vocabulary knowledge gains of each participant

With a small number of participants, it is also useful to look at the gains made by individuals to determine whether the size of their gains also increased as the number of readings increased. The vocabulary mastery levels of the five participants in this study (see Table 23) varied to a large extent, so it is necessary to consider the potential effect of vocabulary mastery level on incidental learning of L2 technical vocabulary. Participants 1, 2, and 3 had mastered the 3000 English vocabulary level. Participant 4 had mastered the 5000 English vocabulary level. Participant 5 had mastered the 4000 English vocabulary level. The vocabulary mastery levels of participant 1, 2, and 3 are lower than those of participants 4 and 5. Thus, the vocabulary knowledge gains of participants 1, 2, and 3 were examined separately from those of participant 4 and 5. The results showed that for participants with lower vocabulary mastery levels, it is uncommon to observe a consistent increase of vocabulary gains with the increase in the number of readings. However, from participants with higher vocabulary mastery levels, it is common to see partially consistent increases in vocabulary gains.

Table 22 Incidental vocabulary gains (pretest to post-test) of each participant.

ID of participants	number of readings	The texts	receptive form-meaning gains and retention				productive written form gains and retention			
			Maximum score	Pre-test score	Pre-test to post-test gains	Pre-test to delayed post-test retention	Total score of all target items from each text	Pre-test score	Pre-test to post-test gains	Pre-test to delayed post-test retention
1	1 time	Anatomy	18	2.5	3.5[1] (22.58%)[2]	3 (19.35%)	19	4	3 (18.75%)	5 (31.25%)
	2 times	Film	19	2.5	0 (0.00%)	0 (0.00%)	20	5	3 (20.00%)	4 (26.67%)
	3 times	Biology	19	3	5 (31.25%)	6.5 (40.63%)	19	5	5 (35.71%)	7 (50.00%)
	4 times	Geology	20	1	1.5 (07.89%)	3 (15.79%)	20	4	-1 (-6.25%)	3 (18.75%)
2	1 time	Biology	19	3	3.5 (21.88%)	3 (18.75%)	19	11	3 (37.50%)	2 (25.00%)
	2 times	Geology	20	6	7 (50.00%)	6.5 (46.43%)	20	5	9 (60.00%)	9 (60.00%)
	3 times	Anatomy	18	7	2.5 (22.73%)	4 (36.36%)	19	7	6 (50.00%)	6 (50.00%)
	4 times	Film	19	3.5	5 (32.26%)	5 (32.26%)	20	8	3 (25.00%)	4 (33.33%)
3	1 time	Film	19	2.5	0 (0.00%)	0 (0.00%)	20	4	0 (0.00%)	2 (12.50%)
	2 times	Anatomy	18	7	1.5 (9.68%)	1 (6.45%)	19	8	-1 (-9.09%)	3 (27.27%)
	3 times	Geology	20	0.5	2.5 (12.83%)	2.5 (12.82%)	20	2	4 (22.22%)	2 (11.11%)
	4 times	Biology	19	4	1 (5.41%)	2.5 (13.51%)	19	3	8 (50.00%)	9 (56.25%)
4	1 time	Geology	20	6	3 (21.43%)	3 (21.43%)	20	7	10 (76.92%)	11 (84.62%)
	2 times	Biology	19	8	1 (9.09%)	0.5 (4.55%)	19	8	3 (27.27%)	3 (27.27%)
	3 times	Film	19	7.5	4.5 (39.13%)	2.5 (21.74%)	20	11	3 (33.33%)	5 (55.56%)
	4 times	Anatomy	18	6.5	6.5 (56.52%)	5.5 (47.83%)	19	11	6 (66.67%)	5 (62.50%)
5	1 time	Geology	20	2	2.5 (13.89%)	2 (11.11%)	20	4	6 (37.50%)	8 (50.00%)
	2 times	Biology	19	7.5	0.5 (4.35%)	1 (8.70%)	19	11	2 (25.00%)	5 (62.50%)
	3 times	Film	19	3.5	1 (6.45%)	1 (6.45%)	20	6	5 (35.71%)	9 (64.29%)
	4 times	Anatomy	18	4	5 (35.71%)	5 (35.71%)	19	11	5 (62.50%)	7 (87.50%)

Note: [1]= the raw gains; [2]=relative gains.

Table 23 Scores of Updated Vocabulary Levels test of each participant.

ID of participants	Scores of current levels	Scores of following levels
1	3000 level: 28/30	4000 level: 24/30
2	3000 level: 30/30	4000 level: 24/30
3	3000 level: 28/30	4000 level: 24/30
4	5000 level: 30/30	N/A
5	4000 level: 26/30	5000 level: 23/30

Note. A score of 26/30 indicates mastery of a level (Schmitt et al, 2001)

4.1.2.1 The gains in receptive knowledge of form-meaning connection of each participant.

The results showed that the gains in receptive knowledge of form-meaning connection tended to increase consistently for participants 4 and 5. Table 22 indicates that for participant 4, from reading 1 to 2 times, the gains decreased from 21.43% to 9.09%, but after reading 3 times, the gains increased to 39.13%. After reading 4 times, the gains further increased to 56.00%. For participant 5, from reading 1 to 2 times, the gains decreased from 13.89% to 4.35%. After reading 4 times, the gains further increased to 37.93%.

However, the pattern that occurred with participants 4 and 5 did not occur with participants 1, 2 and 3. The gains of participant 1 from reading 1 to 2 times decreased from 22.58% to 0.00%, but after 3 times, the gains increased to 31.25%. After reading 4 times, the gains decreased to 7.89%. The gains of participant 2 from reading 1 to 2 times increased from 18.75% to 46.43%. After reading 3 times, the gains decreased to 36.36%, and after reading 4 times, the gains further decreased to 32.26%. Only the gains of participant 3 showed a partially consistent increase. From reading 1 to 2 times, the gains for participant 3 increased from 0.00% to 9.68%. After reading 3 times, the gains further increased to 12.83%. But after reading 4 times, the gains decreased to 5.41%.

4.1.2.2 The gains in productive knowledge of written form

The gains in productive knowledge of written form repeat the trend of the gains in receptive knowledge of form-meaning connection: the gains for participants with higher vocabulary mastery levels tended to increase consistently. Both participants with higher vocabulary mastery levels had partially consistent increases in gains as the number of readings increased from 2 to 4 times. As shown in Table 22, from reading 1 to 2 times, the gains for participant 4 decreased from 76.92% to 27.27%. After reading three times, the gains of participant 4 increased to 33.33%, and after reading 4 times, the gains further increased to 66.67%. From reading 1 to 2 times, the gains for participant 5 decreased from 37.50% to 25.00%. After reading 3 times, the gains increased to 35.71%, and after reading 4 times, the gains further increased to 62.50%.

However, this pattern was only observed for 2 out of 3 participants with lower vocabulary mastery levels when the gains in productive knowledge of written form were examined. The gains of participant 1 from reading 1 to 2 times increased from 18.75% to 20.00%, and after 3 readings, the gains further increased to 35.71%. After reading 4 times, the gains of participant 1 sharply decreased to -6.25%. From reading 1 to 2 times, the gains for participant 3 decreased from 0.00% to -9.09%. After reading 3 times, the gains increased to 22.22%. After reading 4 times, the gains further increased to 50.00%. However, this pattern was not observed with participant 2. The gains of participant 2 increased from 37.50% to 60.00% from reading 1 to 2 times. After reading 3 times, the gains decreased to 50.00%, and after reading 4 times, the gains further decreased to 25.00%.

4.1.3 Vocabulary knowledge gains within each text.

The vocabulary gains were also compared in a cross-subject/within text manner to determine whether the size of the vocabulary gains increase as the number of readings increase across texts. Participants 4 and 5 read the same texts the same number of times, while all the others read different texts with different frequencies (see Table 24). Consequently, two comparisons were made. The data from participants 1, 2, 3, were compared with those from participant 5; then the data from participants 1, 2, 3, were compared with those from participant 4. The results (see Table 25 and 26) showed that the vocabulary gains did not always increase with the number of readings for either receptive knowledge of from-meaning connection or productive knowledge of written form in either comparison. However, the partial consistency between the number of readings and the vocabulary gains happened to some texts, such as the Anatomy text.

Table 24 The reading schedules of all participants.

	Geology text	Biology text	Film text	Anatomy text
1 time	Participants 4 and 5	Participant 2	Participant 3	Participant 1
2 times	Participant 2	Participants 4 and 5	Participant 1	Participant 3
3 times	Participant 3	Participant 1	Participants 4 and 5	Participant 2
4 times	Participant 1	Participant 3	Participant 2	Participants 4 and 5

4.1.3.1 The gains in receptive knowledge of form-meaning connection within each text

The gains in receptive knowledge of form-meaning connection were examined for participants 1, 2, 3, and 5. The results showed that as the number of readings increases, only the size of gains from the Film text and the Anatomy text tended to consistently increase. As shown in Table 25, the gains from Film text in receptive knowledge of form-meaning connection were 0.00% after reading 1 and 2 times. However, the gains increased to 6.45% after reading 3 times, and after reading 4 times the gains further increased to 32.26%. From reading 1 to 2 times, the gains from the Anatomy text decreased from 21.21% to 9.09%. But the gains increased to 21.74% after reading 3 times, and after reading 4 times the gains further increased to 37.93%. A similar pattern was detected when the gains of participant 1, 2, 3, and 4 were examined: as the number of readings increased, only the gains from the Anatomy text tended to increase consistently. As shown in Table 25, from reading 1 to 2 times, the gains from the Anatomy text decreased from 21.21% to 9.09%. Then after reading it 3 times, the gains increased to 21.74%, and the gains further increased to 56.00% after the 4th reading.

Table 25 Raw and relative gains and retentions of technical vocabulary knowledge from different texts (including participant 5) (n=4)

The number of reading times	Raw and relative gains in receptive knowledge of form-meaning connection				Raw and relative gains in productive knowledge of written forms			
	Geology text	Biology text	Film text	Anatomy text	Geology text	Biology text	Film text	Anatomy text
1 time	2.5[1] (13.89%[2]) (5[3])	3.5 (21.88%) (2)	0 (0.00%) (3)	3.5 (22.58%) (1)	6 (37.50%) (5)	3 (37.50%) (2)	0 (0.00%) (3)	3 (18.75%) (1)
2 times	7 (50.00%) (2)	0.5 (4.35%) (5)	0 (0.00%) (1)	1.5 (9.68%) (3)	9 (60.00%) (2)	2 (25.00%) (5)	3 (20.00%) (1)	-1 (-9.09%) (3)
3 times	2.5 (12.82%) (3)	5 (31.25%) (1)	1 (06.45%) (5)	2.5 (22.73%) (2)	4 (22.22%) (3)	5 (35.71%) (1)	5 (3.71%) (5)	6 (50.00%) (2)
4 times	1.5 (07.89%) (1)	1 (5.41%) (3)	5 (32.26%) (2)	5 (35.71%) (5)	-1 (-6.25%) (1)	8 (50.00%) (3)	3 (25.00%) (2)	5 (62.50%) (5)

Note: [1]=raw gains or retentions, [2]=relative gains or retentions, [3]=the ID number of participants who read the text for certain number of times

Table 26 Raw and relative gains of form-meaning connection from different texts (including participant 4) (n=4)

The number of reading times	Raw and relative gains in receptive knowledge of form-meaning connection				Raw and relative gains in productive knowledge of written forms			
	Geology text	Biology text	Film text	Anatomy text	Geology text	Biology text	Film text	Anatomy text
1 time	3[1] (21.43%[2]) (4[3])	3.5 (21.88%) (2)	0 (0.00%) (3)	3.5 (22.58%) (1)	10 (76.92%) (4)	3 (37.50%) (2)	0 (0.00%) (3)	3 (18.75%) (1)
2 times	7 (50.00%) (2)	1 (9.09%) (4)	0 (0.00%) (1)	1.5 (9.68%) (3)	9 (60.00%) (2)	3 (27.27%) (4)	3 (20.00%) (1)	-1 (-9.09%) (3)
3 times	2.5 (12.82%) (3)	5 (31.25%) (1)	4.5 (39.13%) (4)	2.5 (22.73%) (2)	4 (22.22%) (3)	5 (35.71%) (1)	3 (33.33%) (4)	6 (50.00%) (2)
4 times	1.5 (07.89%) (1)	1 (5.41%) (3)	5 (32.26%) (2)	6.5 (56.52%) (4)	-1 (-6.25%) (1)	8 (50.00%) (3)	3 (25.00%) (2)	6 (75.00%) (4)

Note: [1]=raw gains or retentions, [2]=relative gains or retentions, [3]=the ID number of participants who read the text for certain number of times

4.1.3.2 The gains in productive knowledge of written form within each text.

The comparisons of gains in productive knowledge of written form repeat the inconsistency shown in the gains in receptive knowledge of form-meaning connection. The partial consistency between the number of readings and the gains occurred only for the gains from some texts. When the gains for participants 1, 2, 3, and 5 were examined, the gains from the Biology, Film, and Anatomy texts increase with the number of readings. For instance, as shown in Table 25, from reading 1 to 2 times, the gains from the Biology text decreased from 37.0% to 25.00%. However, the gains increased to 35.71% after reading three times, and the gains further increased to 50.00% after the 4th reading. For the gains from the Film text, there was a similar pattern. The gains increased from 0.00% to 20.00% between the 1st and the 2nd readings. The gains increased to 35.71% after reading three times, but the gains decreased to 25.00% after four readings.

A similar pattern was found when the gains for participant 1, 2, 3, and 4 were compared: the partial consistency between the number of readings and the gains happened only for the gains from some texts. For example, the gains from the Anatomy text decreased from 18.75% to -9.09% between the 1st and the 2nd readings. However, the gains increased to 50.00% after reading three times, and they further increased to 75.00% after the 4th reading.

4.2 Do frequency of encounters and pictorial contexts affect the incidental learning of technical vocabulary through repeated reading of academic texts?

4.2.1 The effect of frequency of encounters.

The frequency of encounters with unknown words for each participant was calculated this way due to the small number of participants in this study:

$$\text{the frequency of unknown words in one text} * \text{number of times the text is read}$$

To evaluate the effect of frequency of encounters on the incidental learning of technical vocabulary, Pearson's *r* was calculated. As shown in Table 27, no statistically significant correlation was found between the frequency of encounters and the raw gains in either receptive knowledge of form-meaning connection (N=380, r=0.075, p=0.144) or productive knowledge of written forms (N=385, *r*=0.074. *p*=0.147).

Table 27 Pearson's r correlation test on frequency of encounters and vocabulary knowledge gains.

		Frequency of encounters	Raw gains in receptive knowledge of form-meaning connection
Frequency of encounters	Person's r		
	p-value		
Raw gains in receptive knowledge of form-meaning connection	Person's r	0.075	
	p-value	0.144	
Raw gains in productive knowledge of written forms	Person's r	0.074	0.093
	p-value	0.147	0.068

4.2.2 The effect of pictorial contexts

The vocabulary knowledge gains of target items included in pictorial contexts and not included in pictorial contexts were compared to detect whether the existence of pictorial contexts affects the incidental learning of technical vocabulary through repeated reading of academic texts. The results indicate that the inclusion of pictorial contexts does not affect the incidental learning of L2 technical vocabulary through repeated reading of academic texts. As shown in Table 28, the gains of the items without pictorial contexts are higher than the gains with pictorial contexts for both the gains in receptive knowledge of form-meaning connection and in productive knowledge of written form. The mean gain in productive knowledge of written form for items included in pictorial contexts was 34.67% which was smaller than the gain for target items not included in pictorial contexts (M=38.51%). Similarly, the mean gain in receptive knowledge of form-meaning connection for target items included in pictorial contexts was 22.85% which was slightly smaller than the gain for target items that were not included in pictorial contexts (M=22.98%).

Table 28 The vocabulary knowledge gains from target items included in pictorial contexts and those not included in pictorial contexts

Participants' ID	Gains of productive knowledge of written forms		Gains of receptive knowledge of form-meaning connection of target items	
	Gains for items included in pictorial contexts (n=39)	Gains from items not included in pictorial contexts (n=39)	Gains from items in pictorial contexts (n=39)	Gains from items without pictorial contexts (n=37)
1	14.81%	15.63%	13.24%	20.00%
2	45.45%	48.00%	34.48%	34.48%
3	20.00%	24.14%	12.50%	8.06%
4	47.62%	70.00%	36.17%	33.33%
5	45.45%	34.78%	17.86%	19.05%
Mean (N=5)	34.67%	38.51%	22.85%	22.98%

When the vocabulary gains for target items included in pictorial contexts with different ratings for informativeness were compared, the results showed that the informativeness of pictorial contexts affected the incidental learning of technical vocabulary. In the *Method* section, the pictorial contexts were organized into 3 categories based on their informativeness. However, since only two target items were included in point 1 pictorial contexts, the three points of pictorial contexts were categorized into two pictorial context bands: point 1 to 2 pictorial contexts (n=16) and point 3 pictorial contexts (n=23).

Table 29 Vocabulary knowledge gains of target items involved pictorial contexts with different levels of informativeness

ID of participants	Informativeness bands of pictorial contexts	Relative gains of receptive knowledge of form-meaning connection aspect of target items	Relative gains of productive knowledge of written forms of target items
1	1 to 2 (n=16)	4.17%	12.50%
	3 (n=23)	20.45%	15.79%
2	1 to 2 (n=16)	38.57%	16.67%
	3 (n=23)	32.43%	56.25%
3	1 to 2 (n=16)	3.57%	33.33%
	3 (n=23)	16.67%	15.79%
4	1 to 2 (n=16)	43.75%	42.86%
	3 (n=23)	22.58%	50.00%
5	1 to 2 (n=16)	10.00%	50.00%
	3 (n=23)	16.67%	42.86%
Mean	1 to 2 (n=16)	18.85%	26.07%
	3 (n=23)	25.70%	35.20%

Table 29 shows that the more informative the pictorial contexts are, the more likely that the unknown L2 technical vocabulary could be learned incidentally. The mean (M=25.70%) gain in receptive knowledge of form-meaning connection for the point 3 band were larger than the mean (M=18.85%) gains for the point 1 and 2 band. The mean (M=35.20%) gain in productive knowledge of written form for the point 3 band were also larger than the mean (M=26.07%) gains for the point 1 and 2 band.

5. Discussion

The present study is the first to investigate the effect of repeated reading of academic texts on incidental learning of L2 technical vocabulary. Earlier studies (Han & Chen, 2010; Horst & Meara, 1999; Todd & Liu, 2014; Webb & Chang, 2012) investigated the effect of repeated reading of non-academic texts on incidental learning of FL vocabulary. Moreover, the dependent measures in this study were sensitive to vocabulary knowledge gains and avoided the weaknesses of the self-evaluating measurements which were used in some earlier studies (Horst & Meara, 1999; Webb & Chang, 2012). Additionally, the relationship between the frequency of encounters and the efficiency of incidental learning of L2 technical vocabulary was also examined under the context of repeated reading. The effect of pictures which are common in academic texts on the incidental learning of L2 technical vocabulary through repeated reading was also investigated. With the use of sensitive measurement instruments and the examination of multiple factors, the present study provides a detailed study of the extent to which L2 technical vocabulary can be incidentally learned through repeated reading of academic texts.

5.1 To what extent do adult L2 learners for academic purposes incidentally learn L2 technical vocabulary in academic texts through repeated reading?

To understand to what extent L2 technical vocabulary could be learned through repeated reading of academic texts, two hypotheses were proposed. The first was that repeated reading of academic texts promotes the incidental learning of technical vocabulary. The second was that as the number of readings increases, the incidental vocabulary gains increase.

The results suggest that repeated reading of academic texts promotes the incidental learning of L2 technical vocabulary which is consistent with the findings of earlier studies (Han & Chen, 2010; Horst & Meara, 1999; Todd & Liu, 2014; Webb & Chang, 2012). The descriptive statistics showed that after reading the texts repeatedly, for both receptive knowledge of form-meaning connection and productive knowledge of written form, there were vocabulary knowledge gains. The vocabulary gains from each participant indicate that after reading the texts repeatedly (reading texts at least twice), on 14 out of 15 post-tests, the participants showed gains in receptive knowledge of form-meaning connection (see Figure 4). Similarly, on 13 out of 15 post-tests, the participants showed gains in productive knowledge of written form (see Figure 5). Additionally, for 4 out of 5 participants, the gains in receptive knowledge of form-meaning connection after reading 3 times were higher than the gains after reading 1 time (see Figure 4). Similarly, for 4 out of 5 participants, the gains in receptive knowledge of form-meaning connection after reading 4 times were higher than the gains after reading 1 time (see Figure 5).

Figure 3 Mean relative gains in vocabulary knowledge of all participants

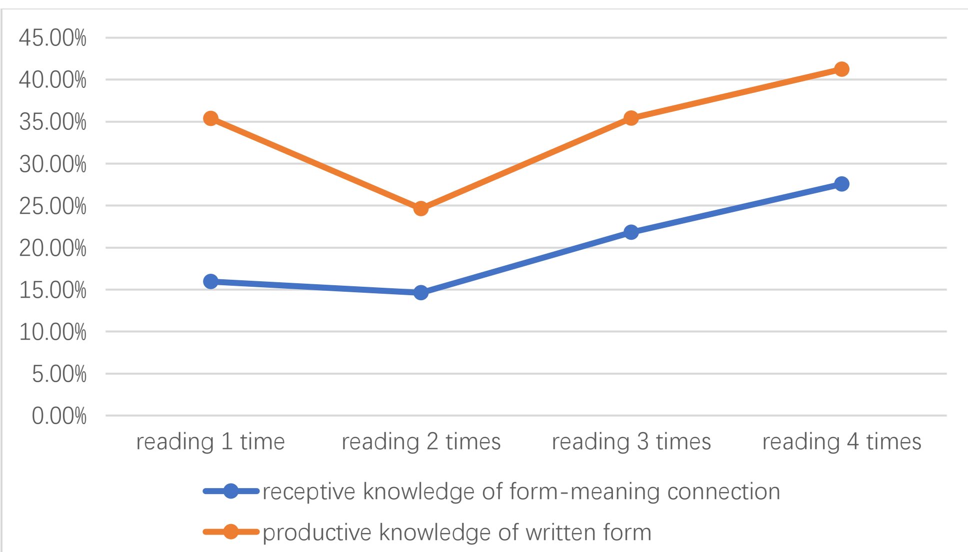


Figure 4 Gains in receptive knowledge of form-meaning connection of each participant from reading different number of times

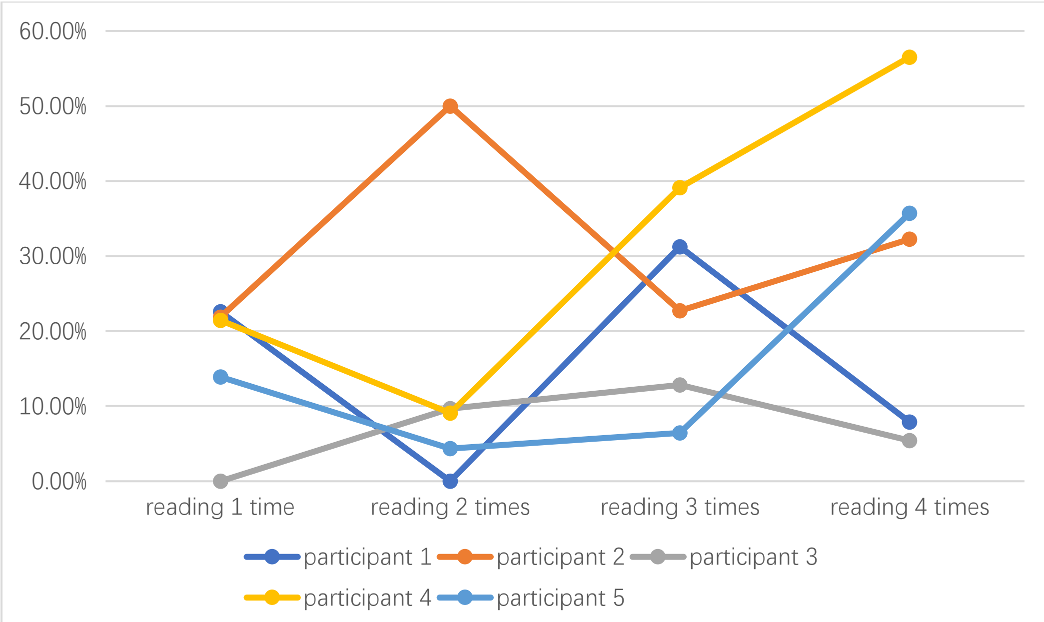
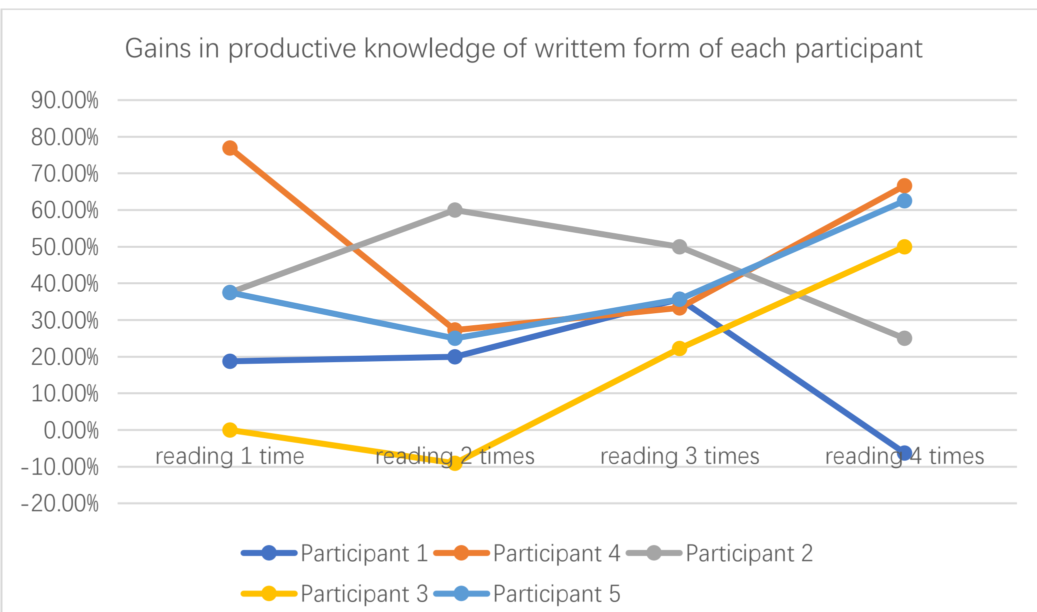


Figure 5 Gains in productive knowledge of written form of each participant from different numbers of readings



The results also suggest that the incidental learning of productive knowledge of written form benefits much more from repeated reading of academic texts than that of receptive knowledge of form-meaning connection. The descriptive statistics show that on average, after reading the academic texts repeatedly, the gains in productive knowledge of written forms were much larger than the gains in receptive knowledge of form-meaning connection (see Figure 3). For 11 out of 15 comparisons, the gains in productive knowledge of written form were larger than the gains in receptive knowledge of form-meaning connection (see Table 22). This confirms the findings of previous studies (Pigada & Schmitt; 2006; Schmitt, 1998) indicating that knowledge of written form benefits the most from L2 reading and that spelling is the aspect that is learned the fastest incidentally.

The higher gains in productive knowledge of written form revealed in this study are particularly useful to EFL learners. Laufer (1997) and Fraser (2012) suggested that sometimes it is easy to misspell English words because occasionally an English written word provides no pronunciation cues. Additionally, for EFL learners with a different L1 writing system such as Chinese, Japanese, and Arabic, it is common to have errors in spelling in English. Therefore, repeated reading might be especially useful for promoting incidental gains in the spelling of L2 technical vocabulary for EFL learners with a different L1 writing system.

The second hypothesis that the L2 technical vocabulary gains increase according to the increase in the number of times the academic texts were read was partially supported by the descriptive statistics. The average vocabulary gains were partially consistent with the findings from the study by Horst and Meara (1999) that indicated that the more times a text is read, the more likely incidental learning of L2 vocabulary occurs. For both receptive knowledge of form-meaning connection and productive knowledge of written form, the vocabulary gains increased as the number of readings increased from 2 to 4 times. However, in contrast the average vocabulary gains decreased as the number of readings increased from 1 to 2, which is not consistent with the findings of Horst and Meara (1999). This contrast in findings might be explained by individual differences and differences in texts.

The differences in vocabulary knowledge (Qian, 1999; 2002) and academic English proficiency (Vidal, 2011) among participants might be responsible for the variation in findings between this study and Horst and Meara (1999). The vocabulary gains in the present study are from different participants reading different texts whereas those in Horst and Meara (1999) were from one participant reading one text repeatedly. Based on the scores of the UVLT and the length of residency in English-speaking countries (Hakuta et al, 2000), we can conclude that in the present study, the participants' breadth of vocabulary knowledge and academic English proficiency varied to a large extent. Research suggests that people with more vocabulary knowledge incidentally learn more L2 vocabulary through reading than those who know fewer words (Tekmen & Daloglu, 2006; Webb & Chang, 2015; Zahar et al., 2001). Similarly, Vidal (2011) reported that academic English proficiency substantially affected the incidental learning of L2 vocabulary from reading academic texts. Some studies have also indicated that higher English proficiency makes it more likely that a person can comprehend a reading text (Cain et al., 2004; Uccelli et al., 2015; Perfetti & Stafura, 2014). Precise comprehension of texts provides readers with greater potential to incidentally guess and learn the meanings of unknown words than less precise comprehension (Beck et al., 1983; Webb, 2007, 2014).

Difficult academic language in texts might also have led to the differences in vocabulary knowledge gains found in the present study. The texts in the present study were authentic academic English texts while the text used by Horst and Meara was a comic storybook (Horst & Meara, 1999, p. 314). One reason to investigate the effect of repeated reading on incidental learning of L2 vocabulary is that repeated reading promotes reading comprehension (Alessi et al., 1983; Millis, Simon, & Tenbroek, 1998; Raney, 2003; Tenpenny; 1995; Rawson, Dunlosky, & Thiede, 2000; Zwaan, Magliano, & Graesser; 1995). After reading the academic texts repeatedly, the participants' improved reading comprehension may make it easier for them to learn technical vocabulary incidentally (Webb, 2007, 2008; Beck et al., 1983). In this study, it is possible that when the texts were only read twice, the positive effect of repeated reading on reading comprehension often could not overcome the negative effect of language difficulty.

Another possible reason for the different results after reading a text 1 and 2 times in the present study and in Horst and Meara (1999) is the number and informativeness of pictures in the reading materials used in the two studies. Research indicated that informative pictures promote incidental learning of L2 vocabulary (Chun & Plass, 1996; Kost et al., 1999; Plass et al., 1998; Yoshii & Flaitz, 2002). As described by Horst and Meara, "the story is told almost entirely through dialogue and pictures". The pictures in the comic book should be more in number and in their informativeness than the pictures in academic texts. Therefore, the huge number and the high informativeness of pictures in the reading materials in Horst and Meara (1999) might have contributed to the positive results of Horst and Meara after their participant read their text 1 and 2 times.

The vocabulary gains were also compared in a within-texts/cross-subject manner and a within-subject manner. The results showed variation among the gains for different individuals and for different texts.

The variation in gains suggests that individual differences play an important role in incidental learning of L2 technical vocabulary through repeated reading of academic texts. Individual differences that may affect findings are breadth of vocabulary knowledge (Perfetti & Stafura, 2014; Tekmen & Daloglu, 2006; Webb & Chang, 2015; Zahar et al., 2001), English proficiency (Cain et al., 2004; Uccelli et al., 2015; Perfetti & Stafura, 2014; Vidal, 2011), background knowledge of topics (Droop & Verhoeven, 1998; McNamara, 2001; Pulido, 2003; Taboada et al., 2008), and reading interest of different topics (Gottfried et al., 2005; Taboada et al., 2008).

The results indicate that differences in breadth of vocabulary knowledge likely affected incidental learning of L2 technical vocabulary through repeated reading of academic texts. The data showed that both participants with greater vocabulary knowledge (participants 4 and 5) had vocabulary knowledge gains that tended to increase with the number of readings. However, the three participants with less vocabulary knowledge had less consistent vocabulary knowledge gains. It is therefore likely that greater L2 vocabulary knowledge contributes to increased L2 learning of technical vocabulary through repeated reading of academic text. This is consistant with the findings of previous studies indicating that readers' vocabulary knowledge correlates positively with incidental learning of L2 vocabulary through reading (Cain et al., 2004; Horst et al., 1998; Webb & Chang, 2015; Zahar et al., 2001). This is intuitively logical because the higher the readers' L2 vocabulary knowledge, the more likely that the readers will know most words in the texts, and this in turn promotes reading comprehension (Hu & Nation, 2006; Laufer, 1989; Nation, 2013). With better reading comprehension, the contexts containing unknown words could be highly informative to readers. Research (Beck et al., 1983; Webb, 2008; Webb & Nation, 2017) suggested that the more informative the contexts containing unknown words are, the more likely the words could be incidentally learned.

The other two individual differences likely explaining such variation are background knowledge and interest in the topics. From interaction between the researcher and the participants, it was clear that the participants varied in their background knowledge and interest in the different topics. For instance, participant 2, reported that he liked the Geology text the most and that due to his interest in Geology, he had read content related to geology many times before participating in the experiment. However, to what extent each participant differs in terms of their background knowledge and interest was not clear because such data were not formally collected. Earlier studies suggest that background knowledge and interest in topics affects reading comprehension, and in turn may influence incidental learning of L2 vocabulary (Beck et al., 1983; Droop and Verhoeven, 1998; Gottfried et al., 2005; McNamara, 2001; Taboada et al., 2008; Webb, 2007, 2014). Pulido (2003) also found that a rich background knowledge promoted incidental learning of L2 vocabulary. However, due to the small number of samples in the present study, it is necessary to have further studies investigating the extent to which these individual differences may affect the incidental learning of technical vocabulary through repeated reading of academic texts.

5.2 Do frequency of encounters and pictorial contexts affect the incidental learning of technical vocabulary through repeated reading of academic texts?

To understand the effect of frequency of encounters on incidental learning of L2 technical vocabulary through repeated reading of academic texts, Pearson's *r* correlation test was conducted. However, no correlation between the frequency of encounters with unknown words and vocabulary knowledge gains occurred in this study which contrasts earlier findings (Brown et al., 2008; Nagy et al, 1985; Webb, 2007, 2014; Zahar et al., 2001). There are several reasons why no correlation was found between the frequency of encounters and vocabulary gains occurred. The first reason might be the that frequency of encounters in this study involved encountering words in the same contexts repeatedly rather than in varied contexts. The frequency of encounters with unknown words for each participant was calculated this way due to the small number of participants in this study:

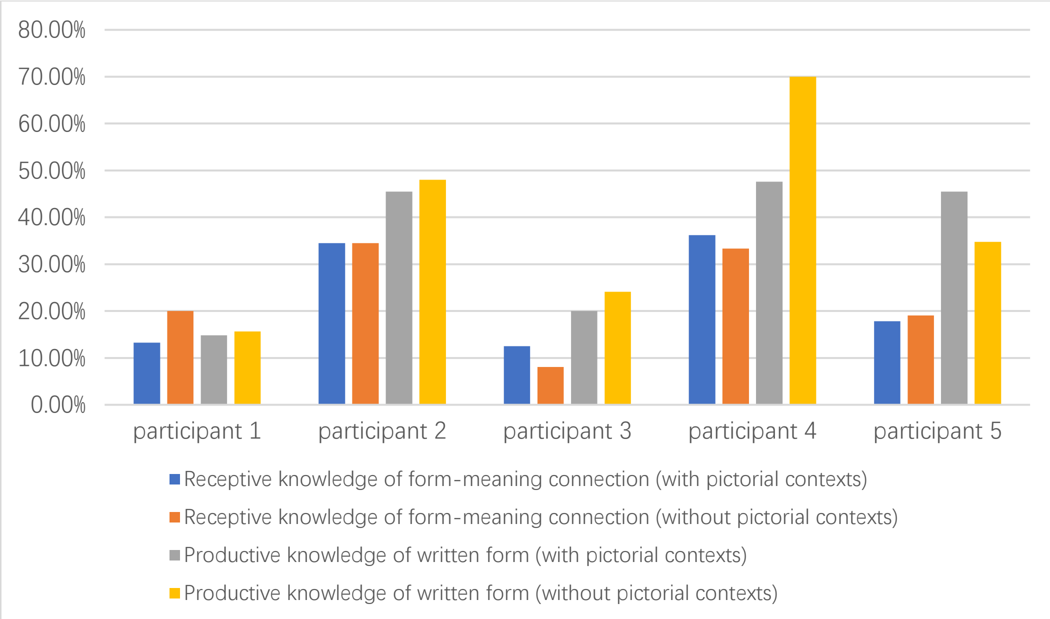
$$\text{the frequency of unknown words in one text} * \text{number of times the text is read}$$

Thus plenty of target words were encountered in the same contexts. For instance, if one participant read the Geology text 4 times, though he or she encountered the item *igneous rock* in the Geology text 8 times, in fact, he or she only encountered the item in two different contexts. Researchers (Joe, 1998; Todd & Liu, 2014; Webb & Nation, 2017) have suggested that the more varied the contexts containing unknown words are, the more likely that the word could be learned incidentally. In earlier studies the participants encountered unknown words in different contexts (Nagy et al, 1985; Webb, 2007, 2014; Brown et al., 2008; Zahar et al., 2001), which might better promote the correlational relationship between the frequency of encounters and incidental vocabulary learning in these studies.

A lack of sensitivity of measures in the present study might also be responsible for the inconsistancy between the findings of this study and previous studies. Occasionally, the measurement instrument for receptive knowledge of form-meaning connection in the present study may not have been sensitive enough to catch partial vocabulary gains. Partial gains in receptive knowledge of form-meaning connection were given 0.5 scores. However, there were occasions when on the post-tests, the participants' partial gains were not large enough to increase partial knowledge to full knowledge. Consequently, in such cases, though small partial gains were shown on post-tests, such gains were not revealed in the post-test scores. It is possible that if small partial gains had been considered, a correlation between the frequency of encounters and the gains in receptive knowledge of form-meaning connection would have occurred. Thus, it would be useful to have further studies with more sensitive measurement instruments to understand the effect of frequency of encounters on incidental learning of L2 technical vocabulary through repeated reading of academic texts.

It is also possible that the effect of informative contexts containing target items counterbalanced the effect of frequency of encounters. This might partially explain the inconsistency between the findings of this and previous studies in terms of the effect of frequency of encounters. Among the 76 (for receptive knowledge of form-meaning connection) and 78 (for productive knwoledge of written form) target items, only 12 target items were included in not very informative contexts (point 1 and 2 contexts). However, the contexts in many previous studies (Brown et al., 2008; Nagy et al, 1985; Webb, 2007) might not be as informative as those in this study since they used narrative texts instead of expository text. Research has shown that the more informative the contexts, the more likely that words encountered in context could be learned incidentally (Beck et al, 1983; Webb, 2007, 2008). Because most target items were encountered in very informative contexts, the effect of frequency of encounters might have been reduced in this study.

Figure 6 Vocabulary knowledge gains for items with and without pictorial items of each participant.



To understand the effect of pictorial contexts on incidental learning of L2 technical vocabulary through repeated readng of academic texts, the vocabulary gains of items with and without pictorial contexts were compared. The vocabulary gains of the items with pictorial contexts were not higher than those without pictorial contexts (see Figure 6), which contrasts earlier findings (Chun & Plass, 1996; Kost et al., 1999; Plass et al., 1998; Yoshii & Flaitz, 2002). Several reasons might be responsible for this constrast such as a lack of informative pictorial contexts, the effect of highly informative textual contexts, and the formal presenting style of the pictures in this study.

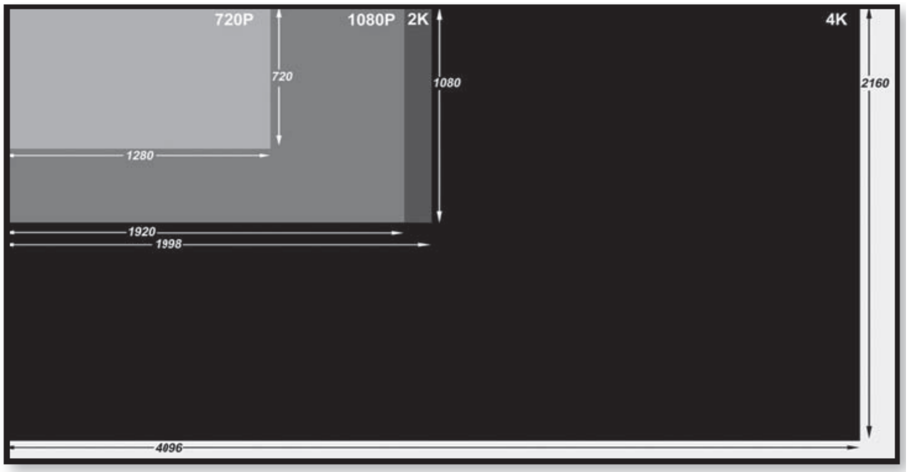
The contrast might be partially explained by the informativeness of the pictorial contexts in the present study and previous studies. The pictures used in previous studies tend to have been very informataive pictorial contexts (Chun & Plass, 1996; Kost et al., 1999; Plass et al., 1998; Yoshii & Flaitz, 2002) since the pictures they used were pictorial glosses. However, among the

39 target items included in pictorial contexts, only 23 of them were included in very informative pictorial contexts in the present study. Earlier studies (Beck et al., 1983; Webb, 2007) suggest that the more informative the contexts, the more likely that words found in the contexts could be incidentally learned. However, in the present study the focus of many pictures was not to illustrate the meanings of target items but instead the concepts of the target items found in pictures were often used to illustrate other concepts. For instance, neither of the two figures including the target item “pixel” illustrated its meaning. This can be seen in Figures 1 and 2. “In *julien donkey-boy,* pixels and grain yield a unique texture, and the high contrast exaggerates pure colors and shapes to create a hallucinatory image” (see Figure 7); (2) “Pixel size of sensors in four standard digital formats” (see Figure 8).

Figure 7 A figure in the Film Studies text containing target item pixel.

1.22 Combining digital video and film. In *julien donkey-boy,* pixels and grain yield a unique texture, and the high contrast exaggerates pure colors and shapes to create a hallucinatory image.

Figure 8 A figure in the Film Studies text containing target item pixel.



1.23 Pixel size of sensors in four standard digital formats. The lowest resolution digital moving image system in common use, 720p, contains 1,280 (width) by 720 (height) pixels, yielding 0.92 megapixels. (A megapixel is 1 million pixels.) 720p is used primarily for U.S. broadcast and cable television and for Internet video. The next step up is 1080 HD, with either progressive or interlaced scanning. HD commonly measures 1,920 by 1,080 pixels, for a total of 2.1 megapixels. The 2K format typically supports 1,998 by 1,080 pixels, yielding 2.2 megapixels. A typical 4K image measures 4,096 by 2,160 pixels, yielding 8.8 megapixels.

It is likely that the attention of participants was drawn into the main focus of the pictures containing target items rather than the meanings of target items. This might explain the relatively low vocabulary knowledge gains of target items included in pictorial contexts. Boers et al. (2017) and Webb and Nation (2017) proposed that it is likely that some pictures reduce readers' noticing of unknown words.

The results of the present study also suggest that among the target items included in pictorial contexts, the more informative the pictorial contexts are, the more likely the items were incidentally learned. This is consistent with the findings of earlier studies (Beck et al., 1983; Boers et al., 2017; Webb, 2008; Webb & Nation, 2013) which indicate that if the meanings of unknown items are the focus of the pictures, it is more likely that unknown words could be incidentally learned. This indicates that not all pictures are equal in promoting incidental learning of L2 vocabulary. It is therefore useful to investigate the characteristics of pictorial contexts such as their informativeness and the foci of pictures to further understand the effect of pictures on incidental learning of L2 technical vocabulary through repeated reading of academic texts.

It is also possible that the postive effect of pictorial contexts was reduced by encountering target items in highly informative textual contexts. As discussed earlier, most target items were included in highly informative textual contexts due to the academic nature of the texts in this study. With enough information provided by textual contexts, it is likely that the help of pictorial contexts was of little value for learning in this study. The texts in previous studies were narrative stories whose contexts were not informative enough for correct guessing of the meanings of words. This might be partially responsible for the relatively high vocabulary gains for target items not included in pictorial contexts in the present study.

Additionally, the contrast between the findings of present and previous studies could be explained by different presentation styles of the pictures. The notes of most pictures in the present study were all in formal style due to the academic nature of the reading texts. For example, the note from Figure 1.23 in the Film text (see Figure 8 of this paper) stated: "*The lowest resolution digital moving image system in common use, 720p, contains 1,280 (width) by 720 (height) pixels, yielding 0.92 megapixels. (A megapixel is 1 million pixels.) 720p is used primarily for U.S. broadcast and cable television and for Internet video*". However, the picture glosses in previous studies were more in conversational style due to the narrative nature of their reading texts (e.g. see Figure 9). According to multimedia learning theory (Mayer, 2014), people learn more deeply from pictures if the words used in pictures are in conversational style or the pictures show a smiling human face. This might explain the relatively high vocabulary knowledge gains from pictorial glosses in previous studies than those in this study.

Figure 9 Pictorial annotation used in Chun and Plass (1996, p. 197) for the word droht (threatens)

In summary, the present study partially supports the use of repeated reading of academic texts to promote incidental learning of L2 technical vocabulary. This suggests that there is value in encouraging EAP students to read academic materials such as their textbooks more than once to learn more English technical vocabulary incidentally. However, it is clear that individual differences play an important role in incidental learning of L2 technical vocabulary through repeated reading of academic texts. Further studies are necessary to investigate the effects of individual differences on incidental learning of L2 technical vocabulary through repeated reading of academic texts.

No correlation was found between frequency of encounters and vocabulary knowledge gains. Results also indicate that the vocabulary gains of words included with pictorial contexts were not higher than the gains of those without pictorial contexts. However, it is likely that the informativeness of pictorial contexts plays a role in incidental learning of L2 technical vocabulary. The effect of different factors such as frequency of encounters and the informativeness of textual contexts may have reduced the influence of pictorial contexts. It is therefore necessary for further studies to explicitly investigate the effects of these factors on the incidental learning of L2 technical vocabulary.

6. Conclusion

This chapter concludes the thesis by providing an overview of the findings and the implications of the study. Directions for future research are also discussed.

6.1 Findings and Implications

This study indicates that adult L2 learners can learn technical vocabulary incidentally through repeated reading of academic texts. Descriptive statistics suggest that as the number of readings increases, vocabulary knowledge gains tend to increase. The average gains in receptive knowledge of form-meaning connection slightly decreased from 15.95% to 14.62% from reading 1 to 2 times; this number increased to 21.83% after reading 3 times and it further increased to 27.56% after reading 4 times. The average gains in productive knowledge of written form decreased from 35.38% to 24.64% from reading 1 to 2 times. However, after reading 3 times, the number increased to 35.40% and after reading 4 times, it further increased to 41.25%. Also, both the descriptive statistics and the vocabulary gains of individuals reveal that there are always vocabulary knowledge gains in both receptive knowledge of form-meaning connection and productive knowledge of written form after reading texts at least twice. For instance, after reading texts at least twice, on 14 out of 15 post-tests, the participants showed gains in receptive knowledge of form-meaning connection and on 13 out of 15 post-tests, the participants showed gains in productive knowledge of written form when looking at individuals' vocabulary knowledge gains. Additionally, the results from 4 out of 5 participants revealed greater gains in both receptive knowledge of form-meaning connection and productive knowledge of written form after reading multiple times than after reading 1 time. Such findings are partially consistent with those of earlier studies (Han & Chen, 2010; Horst & Meara, 1999; Todd & Liu, 2014; Webb & Chang, 2012).

The results of the study also suggest that gains in productive knowledge of written form are larger than those for receptive knowledge of form-meaning connection. For instance, when comparing average gains in receptive knowledge of form-meaning connection and productive knowledge of written form, in 8 out of 8 comparisons the average gains in productive knowledge of written form were 10% more than gains in receptive knowledge of form-meaning connection. Such findings are consistent with those of Pigada and Schmitt (2006) and Schmitt (1998) which found that productive knowledge of written form was acquired in advance of knowledge of the form-meaning connections of unknown words.

The results also suggest that it is possible that individual differences play a significant role in incidental learning of L2 technical vocabulary through repeated reading of academic texts. There was considerable variation in the gains of different individuals and for different texts when looking at the gains in a within-subject manner or in a within-texts/between-subject manner. Though it was expected that increasing the number of readings would lead to higher learning gains, this did not happen to every participant, nor for every text. Research has suggested that many individual differences such as the vocabulary knowledge of readers (Perfetti & Stafura, 2014; Tekmen & Daloglu, 2006; Webb & Chang, 2015; Zahar et al., 2001), readers' background knowledge (Droop & Verhoeven, 1998; McNamara, 2001; Pulido, 2003; Taboada et al., 2008) and interest in different topics (Gottfried et al., 2005; Taboada et al., 2008) might affect incidental learning of L2 technical vocabulary. The results of this study indicate that incidental learning of L2 technical vocabulary through repeated reading of academic texts for individuals with higher vocabulary levels was more predictable than for individuals with lower vocabulary levels. The gains of the participants with higher UVLT scores (participant 4 and 5) tended to increase as the number of readings increased. But only 1 (for the gains in receptive knowledge of form-meaning connection) or 2 (for the gains in productive knowledge of written form) out of 3 participants with lower UVLT scores showed this pattern.

No statistically significant correlation was found between frequency of encounters and vocabulary knowledge gains contrasting the results of earlier studies (e.g. Nagy et al, 1985; Webb, 2007, 2014; Zahar et al., 2001; Yoshii & Flaitz, 2002). It seems that this result is consistent with the suggestion by Nation and Wang (1999) that there is no set number of encounters of an unknown word to ensure the incidental learning of it. Additionally, it seems that frequency of encounters is only one of many factors impacting vocabulary learning (Horst et al, 1998; Webb & Chang, 2015; Webb, 2007, 2008; Webb & Nation, 2017; Yoshii & Flaitz, 2002). However, due to the small size of samples, in this study, the impact of frequency of encounters and pictorial contexts were treated individually.

The comparison between the learning gains of target items with and without pictorial contexts also did not show that the inclusion of pictorial contexts leads to greater vocabulary knowledge gains as suggested by earlier studies (Chun & Plass, 1996; Kost et al., 1999; Plass et al., 1998; Yoshii & Flaitz, 2002). The results also indicate that among the target items included in pictorial contexts, the more informative the pictorial contexts are, the more likely the items were incidentally learned. This finding suggests that pictorial contexts are not the same in terms of informativeness and that it is important to look into the characteristics of different pictures when considering their impact on incidental learning of L2 vocabulary.

The results of this study indicate that it is reasonable to suggest that adult EAP students read their academic texts such as their textbooks more than once if there is a need to learn many technical words in the texts. Additionally, reading academic texts repeatedly is likely to be especially efficient for adult EAP students to learn the spellings of technical words. However, it is also important to be aware that it is not guaranteed that as the number of readings increases, the gains in L2 technical vocabulary will also increase due to the possible impact of individual differences.

6.2 Limitations and Suggestions for Future Research

Two limitations were revealed in the present study. First, it is difficult to make statistical generalization of findings from a case study especially when the participants varied in terms of their vocabulary knowledge and English proficiency to a large extent. This does not mean that the findings of this case study are meaningless. In fact, the findings indicate the need to consider individual differences. This may be less apparent in studies with large sample sizes. Second, in this study, the interactive impact of different factors such as frequency of encounters, textual contexts, and pictorial contexts on incidental learning of L2 technical vocabulary was not examined. Quantitative studies that have previously examined these factors have shown that there is often a correlation between frequency of encounters (Brown et al., 2008; Nagy et al, 1985; Webb, 2007, 2014; Zahar et al., 2001), informativeness of contexts (Beck et al., 1983; Nagy et al., 1987; Webb, 2007, 2008), pictorial contexts (Chun & Plass, 1996; Kost et al., 1999; Plass et al., 1998; Yoshii & Flaitz, 2002) and vocabulary learning. It is likely that these factors impact learning simultaneously. However, no studies have examined all three factors at once. Therefore, it would be useful to carefully examine how the factors interactively contribute to learning. This might then be followed up by more qualitative studies that shed further light on the influence of these factors on vocabulary learning.

Based on the findings, three suggestions were made for future research. First, studies with larger sample sizes are needed. Second, the present study suggests that it is likely that individual differences play an important role in participants' vocabulary knowledge gains. It is therefore valuable for future research investigating the learning of technical vocabulary through repeated reading to investigate the impact of individual differences. Third, it would also be useful for future research to further investigate the impact of textual factors such as frequency of encounters and informativeness of textual contexts and pictorial contexts with a large number of participants in a more traditional quantitative design.

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Appendix

1. The description of the target words of the study

Table 1

The description of the target words from the geological text

Target words	Prompt words	Relevance to reading comprehe-nsion	Part of speech	Concreteness of the word	The number of running words of the target item	Meanings of the target words	The number of aspects of the meaning senses of target words
lattice	repetition	relevant	n.	Concrete word	1	[1]the regular and repeating three-dimensional structure of a mineral	1 meaning sense with 3 aspects
basalt	rock	irrelevant	n.	Concrete word	1	*It is a type of rock. It is a type of igneous rock formed from magma cooled quickly at the surface after a volcanic eruption. It makes up the most part of crust beneath the oceans.	1 meaning sense with 7 aspects
convection	flow	relevant	n.	Concrete word	1	˜ It is a result of transfer of heat It involves the movement of fluid. In a convection, hotter and therefore less dense material to rise, and colder, denser material to sink	1 meaning sense with 4 or 5 aspects
granite	rock	irrelevant	n.	Concrete word	1	*It is a common rock, belonging to igneous rocks. It is formed from magma (molten rock) that has cooled slowly underground.	1 meaning sense with 3 or 4 aspects
schist	rock	irrelevant	n.	Concrete word	1	*A type of metamorphic rocks. It is formed when either igneous or sedimentary rocks are heated and squeezed to the point where some of their	1 meaning sense with 8 or 9 aspects

						minerals are unstable and new minerals form. A type of rock.	
weather	change	irrelevant	v.	Abstract word	1	˜ It is a process of changing. It is to change in color, condition, etc., because of the effects of the sun, wind, rain, etc., over a long period of time.	
igneous rock	magma	relevant	n.	Concrete word	2	*Igneous rocks, a type of rock, form from magma (molten rock) that has either cooled slowly underground (e.g., to produce granite) or cooled quickly at the surface after a volcanic eruption (e.g., basalt)	1 meaning sense with 3 aspects
mantle	flow	relevant	n.	Concrete word	1	*The mantle is made up of iron and magnesium silicate minerals. It is between the core of the Earth and the crust of the Earth. There are three layers of mantle and from the inner Earth to the outer Earth, they are: solid rock (but plastic enough to be able to flow slowly), a partially molten layer (the asthenosphere), the rigid mantle. It is a part of the structure of the Earth.	1 meaning sense with 7 or 8 aspects
sedimentary rock	bury	relevant	n.	Concrete word	2	*Sedimentary rocks, a type of rock, form when the weathered products of other rocks accumulate at the surface and are then buried by other sediments.	1 meaning sense with 3 aspects
metamorphic rock	unstable	relevant	n.	Concrete word	2	*Metamorphic rocks, a type of rock, form when either igneous or sedimentary rocks are heated and squeezed to the point where some of their minerals are unstable and new minerals form to create a different type of rock.	1 meaning sense with 6 aspects

Plate tectonics	movement	relevant	n.	Abstract word	2	˜A theory explaining the structure of the earth's crust and many associated phenomena as resulting from the interaction of rigid lithospheric plates which move slowly over the underlying mantle.	1 meaning sense with 3 or 4 aspects
magnesium	chemical	irrelevant	n.	Concrete word	1	*One of the chemical elements making up the Earth. It makes up Mantle with other elements.	1 meaning sense with 3 aspects
subducted	movement	relevant	v.	Abstract word	1	[1]It is a movement when part of a plate is forced by convective current beneath another plate.	1 meaning sense with 3 or 4 aspects
convergent boundary	earthquake	relevant	n.	Concrete word	2	*It is a place. It is a plate boundary at which two plates are moving towards each other. Earthquakes and volcanoes are common near convergent boundaries.	1 meaning sense with 3 or 4 aspects.
mega annum	time	relevant	n.	Abstract word	2	*A measurement of time. "Millions of years" in geological time	1 meaning sense with 2 or 3 aspects
Asthenosph-ere	mantle	relevant	n.	Concrete word	1	*It is the middle layer of mantle. It is a partially molten layer. It is a part of the structure of the Earth.	1 meaning sense with 2 or 3 aspects
lithosphere	rigid	relevant	n.	Concrete word	1	*The crust and outermost rigid mantle together make up the lithosphere. The lithosphere is divided into about 20 tectonic plates that move in different directions on Earth's surface. A part of the structure of the Earth.	1 meaning sense with 5 or 6 aspects
halite	substance	irrelevant	n.	Abstract word	1	*It is a substance. It is commonly known as rock salt, a type of salt. It is a mineral formed of sodium chloride (NaCl).	1 meaning sense with 3 or 4 aspects
phanerozoic	time	irrelevant	n.	Abstract word	1.	*It is a period of time. It refers to the last 542 million years.	1 meaning

						It is named for the time during which visible (phaneros) life (zoi) is present in the geological record.	sense with 2 or 3 aspects
geothermal gradient	temperature	relevant	n.	Abstract word	2	*the temperature increases with depth, from close to 0°C at the surface to about 7000°C at the centre of the core. In the crust, the rate of temperature increase is about 30°C/km. This is known as the geothermal gradient. It is a phenomenon.	1 meaning sense with 5 or 6 aspects

*: The definitions of the words are from the reading materials.

˜: The definitions of the words are from the consultation of learner's dictionaries.

[1]: The definitions of the words are from the glossary of the textbooks containing the reading materials.

Note: In the "definition of the target words" column, each color represents one aspect.

Table 2

The textual contexts containing the target words from the geological text.

Target words	Frequency in the textual contexts	Textual contexts containing target words	The informativeness of each context containing target words
lattice	2	1. A mineral is a naturally occurring combination of specific elements that are arranged in a particular repeating three dimensional structure or lattice.	Point 3
		2. Even in a tiny crystal, like the ones in your salt shaker, the lattices extend in all three directions for thousands of repetitions.	Point 2
basalt	3	1. Igneous rocks form from magma (molten rock) that has either cooled slowly underground (e.g., to produce granite) or cooled quickly at the surface after a volcanic eruption (e.g., basalt).	Point 4
		2. Examples of rocks are granite, basalt, sandstone, limestone, and schist.	Point 2

		3. The crust — composed mostly of granite on the continents and mostly of basalt beneath the oceans.	Point 2
convection	3	1. Heat is continuously flowing outward from Earth's interior, and the transfer of heat from the core to the mantle causes convection in the mantle (Figure 1.7).	Point 3
		2. This convection is the primary driving force for the movement of tectonic plates.	Point 2
		3. At places where convection currents in the mantle are moving upward, new lithosphere forms (at ocean ridges), and the plates move apart (diverge).	Point 3
granite	5	1. A close-up view of granite, a common rock, is shown in Figure 1.5.	Point 3
		2. Although a hand-sized piece of granite may have thousands of individual mineral crystals in it, there are typically only a few different minerals, as shown here.	Point 2
		3. Igneous rocks form from magma (molten rock) that has either cooled slowly underground (e.g., to produce granite) or cooled quickly at the surface after a volcanic eruption (e.g., basalt).	Point 4
		4. Examples of rocks are granite, basalt, sandstone, limestone, and schist.	Point 3
		5. The crust — composed mostly of granite on the continents and mostly of basalt beneath the oceans — is also rigid.	Point 2
schist	2	1. Metamorphic rocks form when either igneous or sedimentary rocks are heated and squeezed to the point where some of their minerals are unstable and new minerals form to create a different type of rock. An example is schist.	Point 4
		2. Examples of rocks are granite, basalt, sandstone, limestone, and schist.	Point 2
weather	1	1. Sedimentary rocks, such as sandstone, form when the weathered products of other rocks accumulate at the surface and are then buried by other sediments.	Point 3
igneous rock	2	1. Igneous rocks form from magma (molten rock) that has either cooled slowly underground (e.g., to produce granite) or cooled quickly at the surface after a volcanic eruption (e.g., basalt).	Point 4
		2. Metamorphic rocks form when either igneous or sedimentary rocks are heated and squeezed to the point where some of their minerals are unstable and new minerals form to create a different type of rock.	Point 2

mantle	9 (some contexts contain mantle for more than one time).	1. The mantle is made up of iron and magnesium silicate minerals.	Point 2
		2. The bulk of the mantle, surrounding the outer core, is solid rock, but is plastic enough to be able to flow slowly.	Point 3
		3. Surrounding that part of the mantle is a partially molten layer (the asthenosphere), and the outermost part of the mantle is rigid.	Point 3
		4. The crust and outermost rigid mantle together make up the lithosphere.	Point 2
		5. Heat is continuously flowing outward from Earth’s interior, and the transfer of heat from the core to the mantle causes convection in the mantle (Figure 1.7).	Point 3
		6. At places where convection currents in the mantle are moving upward, new lithosphere forms (at ocean ridges), and the plates move apart (diverge).	Point 3
		7. Where two plates are converging (and the convective flow is downward), one plate will be subducted (pushed down) into the mantle beneath the other.	Point 3
sedimentary rock	3	1. The sedimentary rock that these mountains are made of formed in ocean water over 500 million years ago.	Point 2
		2. Sedimentary rocks, such as sandstone, form when the weathered products of other rocks accumulate at the surface and are then buried by other sediments.	Point 4
		3. Metamorphic rocks form when either igneous or sedimentary rocks are heated and squeezed to the point where some of their minerals are unstable and new minerals form to create a different type of rock.	Point 1
metamorphic rock	1	1. Metamorphic rocks form when either igneous or sedimentary rocks are heated and squeezed to the point where some of their minerals are unstable and new minerals form to create a different type of rock.	Point 4
plate tectonics	7	1. 1.5 Fundamentals of Plate Tectonics	Point 1
		2. Plate tectonics is the model or theory that has been used for the past 60 years to understand Earth’s development and structure — more specifically the origins of continents and oceans, of folded rocks and mountain ranges, of earthquakes and volcanoes, and of continental drift.	Point 3
		3. Key to understanding plate tectonics is an understanding of Earth’s internal structure, which is illustrated in Figure 1.6.	Point 2

		4. A few hundred million years later, these beds were pushed east for tens to hundreds of kilometres by tectonic plate convergence and also pushed up to thousands of metres above sea level.	Point 3
		5. The lithosphere is divided into about 20 tectonic plates that move in different directions on Earth's surface.	Point 3
		6. This is followed by a review of Earth's internal structure and the processes of plate tectonics, and an explanation of geological time.	Point 1
		7. This convection is the primary driving force for the movement of tectonic plates.	Point 2
magnesium	2	1. Like everything else in the universe, Earth is made up of varying proportions of the 90 naturally occurring elements— hydrogen, carbon, oxygen, magnesium, silicon, iron, and so on.	Point 4
		2. The mantle is made up of iron and magnesium silicate minerals.	Point 2
subducted	1	1. Where two plates are converging (and the convective flow is downward), one plate will be subducted (pushed down) into the mantle beneath the other.	Point 4
convergent boundary	1	1. 1. Where two plates are converging (and the convective flow is downward), one plate will be subducted (pushed down) into the mantle beneath the other.	Point 4
mega annum	1	1. Using the scientific notation for geological time, that is 4,570 Ma (for mega annum or “"millions of years”) or 4.57 Ga (for giga annum or "billions of years").	Point 4
asthenosphere	1	1. Surrounding that part of the mantle is a partially molten layer (the asthenosphere), and the outermost part of the mantle is rigid.	Point 4
lithosphere	3	1. The crust and outermost rigid mantle together make up the lithosphere.	Point 4
		2. The lithosphere is divided into about 20 tectonic plates that move in different directions on Earth's surface.	Point 3
		3. At places where convection currents in the mantle are moving upward, new lithosphere forms (at ocean ridges), and the plates move apart (diverge).	Point 2
halite	3	1. The mineral halite is shown as an example in Figure 1.4. In this case, atoms of sodium (Na: purple) alternate with atoms of chlorine (Cl: green) in all three dimensions, and the angles between the bonds are all 90°.	Point 4
		2. Halite always has this composition and this structure.	Point 1

		3. Examples of minerals are feldspar, quartz, mica, halite, calcite, and amphibole.	Point 2
phanerozoic	1	1. To create some context, the Phanerozoic Eon (the last 542 million years) is named for the time during which visible (phaneros) life (zoi) is present in the geological record.	Point 4
geothermal gradient	1	2. An important property of Earth (and other planets) is that the temperature increases with depth, from close to 0°C at the surface to about 7000°C at the centre of the core. In the crust, the rate of temperature increase is about 30°C/km. This is known as the geothermal gradient.	Point 4

Table 3

The description of the pictorial contexts containing the target words from the geological text

(Only the target words contained in pictorial contexts are shown in this table).

Target words	Frequency in pictorial contexts	*Pictorial contexts containing the words	Informativeness of the pictorial contexts
lattice	1	Figure 1.4	Point 3
convection	1	Figure 1.7	Point 2
granite	1	Figure 1.5	Point 2
mantle	1	Figure 1.6	Point 3
Subducted (*subduction* in the figure)	1	Figure 1.7	Point 3
asthenosphere	2	Figure 1.6 Figure 1.7	Point 3 Point 3
lithosphere	1	Figure 1.7	Point 3
halite	1	Figure 1.4	Point 3
phanerozoic	1	Figure 1.9	Point 2

*: The numbers of the figure in this column are the original numbers of figures in the reading material.

Table 4

The description of the target words from the biological text

Target words	Prompt words	Relevance to reading comprehension	Part of speech	Concreteness of target words	The number of words in target items	Definitions of the words	The number of aspects of the meaning senses of target words

cataracts	vision	irrelevant	n.	Concrete word	1	˜ It is a medical condition that affects the lens of the eye and causes opaqueness of lens. To people suffering cataracts, the world appears more yellow.	1 meaning sense with 3 or 4 aspects
ophthalmologist	a people	irrelevant	n.	Concrete word	1	˜ A group of people. A doctor who treats eye diseases	1 meaning sense with 2 or 3 aspects
photon	energy	relevant	n.	Concrete word	1	*It is a type of energetic particles. Light is composed of a stream of photons. It is a type of particles.	1 meaning sense with 2 or 3 aspects
electromagnetic radiation	energy	relevant	n.	Abstract word	2	*The energy from the Sun is given off to the Earth through electromegnatic radiation, which travels in the form of a wave at a speed of 1 079 252 848 km/h (the speed of light) and reaches Earth in just over 8 minutes. Different types of electromegnetic radiations have different wavelengths.	1 meaning sense with 4 aspects
particle-wave duality	light	relevant	n.	Abstract word	2	*A wave of eletromegnatic radiation with specific wavelengths that can be detected by human eyes is normally considered light in biology. Energetic particles composing light are called photons. Light has properties of both a wave and a stream of photons is often referred to as the particle-wave duality. It is a property of light.	1 meaning sense with 6 or 7 aspects
carbohydrate	carbon dioxide	relevant	n.	Abstract word	1	˜ It's a type of substance. Sugar that is any one of various substances that are found in plants and that your body uses or stores for energy.	1 meaning sense with 3 or 4 abstracts
photosynthesis	energy	relevant	n.	Abstract word	1	* The process whereby light energy is used by plants and related organisms to convert carbon dioxide into sugars (carbohydrates).	1 meaning sense with 4 or 5 aspects
cellular respiration	energy	relevant	n.	Abstract word	2	*The process of cellular respiration breaks down the products of photosynthesis (such as sugar	1 meaning sense with 4 or 5 aspects

						molecules, carbohydrates) and releases usable chemical energy.	
pigment	molecule	relevant	n.	Concrete word	1	*They are a major class of molecules that are very efficient at absorbing photons are called pigments. There is a large diversity of pigments. The bonding structure between the carbon atoms in the pigments allows the delocalization of electrons in the atoms. Thus, the electrons in the atoms can interact with the photons. Thus, pigments are good at absorbing light. A type of particles.	1 meaning sense with 6 or 7 aspects
conjugated system	structure	relevant	n.	Abstract word	2	*A structure within pigments that allows them to absorb photons. Atoms within pigments are covalently bonded to each other with alternating single and double bonds. It results in the delocalization of electrons so that none of these electrons are closely associated with a particular atom or involved in bonding and thus are available to interact with other electrons. This bonding system is called conjugated system.	1 meaning sense with 8 or 9 aspects
photoreceptor	light	relevant	n.	Concrete word	1	*The basic light-sensing system/cell/organ in organisms is termed the photoreceptor	1 meaning sense with 2 or 3 aspects
rhodopsin	particle	relevant	n.	Concrete word	1	*It's the most common photoreceptor in nature which is the basis of vision in animals but is also very common in other organisms. Each photoreceptor cell contains thousands of individual rhodopsin molecules.	1 meaning sense with 5 or 6 aspects
opsin	protein	relevant	n.	Abstract word	1	*A type of particle. A protein forms part of the visual pigment rhodopsin. Opsin binds another pigment molecule called retinal. Upon	1 meaning sense with 4 or 5 aspects

						absorption of a photon of light, retinal changes shape, which triggers changes to the opsin molecule.	
retinal	particle	relevant	n.	Abstract word	1	*A pigment molecule which is involved in vision and sensing light. It is bound by an opsin (protein) of rhodopsin. With the absorption of a photon of light, retinal changes shape, which triggers changes to the opsin molecule. This allow the organism to respond to the light.	1 meaning sense with 9 aspects
eyespot	light	relevant	n.	Concrete word	1	*The eyespot is a light-sensitive structure within individual cells allowing individual cells to gather information about the location and intensity of a light source.	1 meaning sense with 6 or 7 aspects
chloroplast	cell	relevant	n.	Concrete word	1	*A structure in cells. It is a structure in plant cells in which photosynthesis takes place and which contains an eyespot for sensing light	1 meaning sense with 4 or 5 aspects
phytochrome	light	relevant	n.	Abstract word	1	*It is an object. It is a photoreceptor in the cytosol of all plant cells. It is for photomorphogenesis, the normal developmental process. This process is activated when seedlings are exposed to light. This process activates hundreds of genes after the phytochrome sense light. These genes are crucial for photosynthesis and leaf development and other developments of plants.	1 meaning sense with 8 or 9 aspects
Halobacterium	organism	relevant	n.	Concrete word	1	*One genus of organisms (Archaea) that does not use the light energy to convert carbon dioxide into carbohydrates. ,	1 meaning sense with 1 or 2 aspects
algae	plant	irrelevant	n.	Concrete word	1	˜A type of organism. It's a type of very simple plants, such as seaweed. They have no real leaves,	1 meaning sense with 4 or 5 aspects

stems or roots. They grow in or near water. *They sense light with eyespots rather than eyes.

*: The definitions of the words are from the reading materials.

˜: The definitions of the words are from the consultation of learner's dictionaries.

Note: the definitions of target items consist of different aspects. Diverse aspects are written in different colors.

Table 5

The description of the textual contexts containing the target words from the geological text

Target words	Frequency in the textual contexts	Contexts containing target words	The informativeness of the textual contexts containing the target words
cataracts	3	1. Monet suffered from cataracts, a vision-deteriorating disease diagnosed in both eyes by a Parisian ophthalmologist in 1912 when Monet was 72.	Point 3
		2. A cataract is a change in the lens of the eye, making it more opaque. The underlying cause is a progressive denaturation of one of the proteins that make up the lens. The increased opaqueness of the lens absorbs certain wavelengths of light, decreasing the transmittance of blue light.	Point 4
		3. Thus, to a cataract sufferer such as Monet, the world appears more yellow.	Point 2
ophthalmologist	1	Monet suffered from cataracts, a vision-deteriorating disease diagnosed in both eyes by a Parisian ophthalmologist in 1912 when Monet was 72.	Point 3
photon	22	1. As well, although the results of some experiments suggest that light behaves as a wave as it travels through space, the results of other experiments are best explained by light being composed of a stream of energy particles called photons.	Point 4
		2. That light has properties of both a wave and a stream of photons is often referred to as the particle-wave duality.	Point 1
		3. And so we are left with a compromise description—light is best understood as a wave of photons.	Point 1
		4. The relationship between the wavelength of light and the energy of the photons it carries is an inverse one: the	Point 2

		longer the wavelength, the lower the energy of the photons it contains.	
		5. Looking at Figure 1.3, this means that shorter-wavelength blue light consists of photons of higher energy than red light, which has a longer wavelength and photons of lower energy.	Point 2
		6. When a photon of light hits an object, the photon has three possible fates: it can be reflected off the object; transmitted through the object; or, it can be absorbed by the object.	Point 1
		7. The energy of the photon is transferred to an electron within a molecule.	Point 1
		8. An important fact to remember is that a photon can be absorbed by an electron of a molecule only if the photon energy equals the energy difference between the electron's ground state and an excited state.	Point 1
		9. If the energies don't match, then the photon is transmitted through the molecule or reflected.	Point 1
		10. A major class of molecules that are very efficient at absorbing photons are called pigments (Figure 1.5).	Point 1
		11. None of these electrons are closely associated with a particular atom or involved in bonding and thus are available to interact with a photon of light.	Point 2
		12. While some pigments can absorb, for example, only blue photons because they have only one high-energy excited state, others can absorb two or more different wavelengths because they have two or more excited states.	Point 1
		13. Photon absorption is intimately related to the concept of color.	Point 1
		14. A pigment's color is the result of photons of light that it does not absorb.	Point 1
		15. Instead of being absorbed, these photons are reflected off the pigment or transmitted through the pigment to reach your eyes (Figure 1.6).	Point 1
		16. Although the energy of one photon is very small, the photosynthetic apparatus within the chloroplast of a single C. reinhardtii cell absorbs millions of photons each second.	Point 2
		17. The pigment component of bacteriorhodopsin captures photons of light that provide the energy supply needed to pump protons out of the cell.	Point 1
Electromagnetic radiation	3	1. This energy is given off as electromagnetic radiation, which travels in the form of a wave at a speed of 1 079 252 848 km/h (the speed of light) and reaches Earth in just over 8 minutes.	Point 3

		2. Scientists often distinguish different types of electromagnetic radiation by their wavelength, the distance between two successive peaks (Figure 1.3).	Point 2
		3. The wavelength of electromagnetic radiation ranges from less than one picometre (10–12 m) for cosmic rays to more than a kilometer (106 m) for radio waves.	Point 2
particle-wave duality	1	1. That light has properties of both a wave and a stream of photons is often referred to as the particle-wave duality.	Point 4
carbohydrate	6	1. Energy from the Sun enters the biosphere through photosynthesis – the process whereby light energy is used by plants and related organisms to convert carbon dioxide into sugars (carbohydrates).	Point 4
		2. These molecules are in turn consumed in the Calvin cycle of photosynthesis to convert carbon dioxide into carbohydrates (Figure 1.7, p. 6).	Point 3 (with the Figure 1.7)
		3. While photosynthesis converts carbon dioxide into carbohydrates, it is the process of cellular respiration that breaks down carbohydrates and other molecules, trapping the released energy as ATP (see Figure 1.7).	Point 3 (with the Figure 1.7)
		4. That is, some organisms do not use the light energy to convert carbon dioxide into carbohydrates.	Point 1
		5. In Halobacteria the ATP synthesized through bacteriorhodopsin is used for a range of energy-requiring reactions – but not for the synthesis of carbohydrates from carbon dioxide.	Point 1
photosynthesis	7	1. Each cell contains a single large chloroplast that harvests light energy and uses it to make energy-rich molecules through the process of photosynthesis.	Point 4
		2. It is the excited-state electron that represents the source of energy required for processes such as photosynthesis and vision.	Point 2
		3. There is a large diversity of pigments, including chlorophyll a, which is involved in photosynthesis; retinal, which is involved in vision; and indigo, which is used to dye jeans their distinctive blue colour.	Point 1
		4. Energy from the Sun enters the biosphere through photosynthesis – the process whereby light energy is used by plants and related organisms to convert carbon dioxide into sugars (carbohydrates).	Point 4
		5. We discuss this photosynthesis in detail in Chapter 7.	Point 1
		6. These molecules are in turn consumed in the Calvin cycle of photosynthesis to convert carbon dioxide into carbohydrates (Figure 1.7, p. 6).	Point 3
		7. While photosynthesis converts carbon dioxide into carbohydrates, it is the process of cellular respiration	Point 3

		that breaks down carbohydrates and other molecules, trapping the released energy as ATP (see Figure 1.7).	
cellular respiration	1	1. While photosynthesis converts carbon dioxide into carbohydrates, it is the process of cellular respiration that breaks down carbohydrates and other molecules, trapping the released energy as ATP (see Figure 1.7).	Point 3 (with the Figure 1.7)
pigment	13	1. A major class of molecules that are very efficient at absorbing photons are called pigments (Figure 1.5). 2. There is a large diversity of pigments, including chlorophyll a, which is involved in photosynthesis; retinal, which is involved in vision; and indigo, which is used to dye jeans their distinctive blue colour. 3. An important question we can ask is: what is it about pigments that enable them to capture light? 4. Most pigments absorb light at distinctly different wavelengths. 5. While some pigments can absorb, for example, only blue photons because they have only one high-energy excited state, others can absorb two or more different wavelengths because they have two or more excited states. 6. A pigment’s colour is the result of photons of light that it does not absorb. 7. Instead of being absorbed, these photons are reflected off the pigment or transmitted through the pigment to reach your eyes (Figure 1.6). 8. What structural feature is common to all pigments? 9. Following light absorption, the potential energy of excited electrons within pigment molecules such as chlorophyll is used in photosynthetic electron transport to synthesize the energy-rich compounds NADPH (nicotinamide adenine dinucleotide phosphate) and ATP (adenosine triphosphate). 10. Species of Halobacterium contain a pigment–protein complex called bacteriorhodopsin, which functions as a light-driven proton pump. 11. The pigment component of bacteriorhodopsin captures photons of light that provide the energy supply needed to pump protons out of the cell. 12. Why is the pigment indigo blue in colour?	Point 4 Point 2 Point 2 Point 2 Point 2 Point 2 Point 2 Point 1 Point 2 Point 1 Point 1 Point 1
conjugated system	1	1. This bonding arrangement is called a conjugated system, and it results in the delocalization of electrons.	Point 4
photoreceptor	12	1. 1.3a Rhodopsin, the Universal Photoreceptor	Point 1

		2. The basic light-sensing system is termed the photoreceptor.	Point 4
		3. And the most common photoreceptor in nature is rhodopsin (Figure 1.9, p. 8), which is the basis of vision in animals but is also very common in other organisms, including C. reinhardtii, where it serves as the light-sensing unit of the eyespot.	Point 2
		4. In humans, light captured by the eye involves the approximately 125 million photoreceptor cells (rods and cones) that line the retina.	Point 2
		5. Each photoreceptor cell contains thousands of individual rhodopsin molecules.	Point 1
		6. Rhodopsin is the most common photoreceptor found in nature, but it is not the only one.	Point 1
		7. Both plants and animals have a range of other photoreceptors that absorb light of particular wavelengths.	Point 2
		8. However, it remains a mystery why rhodopsin became the most common photoreceptor.	Point 1
		9. The eyespot is composed of two layers of carotenoid-rich lipid globules that seem to play a role in focusing and directing incoming light toward the photoreceptors.	Point 1
		10. Recent research has shown that about 200 different proteins are assembled to produce the eyespot apparatus, including specific opsin proteins that are the basis of the rhodopsin-based photoreceptors.	Point 1
		11. Instead the photoreceptors of the eyespot allow the cell to sense light direction and intensity.	Point 2
		12. In plants, a photoreceptor called phytochrome senses the light environment and is critical for photomorphogenesis, the normal developmental process activated when seedlings are exposed to light (Figure 1.11).	Point 3
rhodopsin	9	1. Rhodopsin, the Universal Photoreceptor	Point 3
		2. And the most common photoreceptor in nature is rhodopsin (Figure 1.9, p. 8), which is the basis of vision in animals but is also very common in other organisms, including C. reinhardtii, where it serves as the light-sensing unit of the eyespot.	Point 4
		3. Each rhodopsin molecule consists of a protein called opsin that binds a single pigment molecule called retinal.	Point 2
		4. As the name suggests, rhodopsin is structurally similar, and evolutionarily related, to the bacteriorhodopsin found in Halobacterium.	Point 2

		5. Each photoreceptor cell contains thousands of individual rhodopsin molecules.	Point 2
		6. Rhodopsin is the most common photoreceptor found in nature, but it is not the only one.	Point 3
		7. However, it remains a mystery why rhodopsin became the most common photoreceptor.	Point 3
		8. Recent research has shown that about 200 different proteins are assembled to produce the eyespot apparatus, including specific opsin proteins that are the basis of the rhodopsin-based photoreceptors.	Point 2
opsin	7	1. Each rhodopsin molecule consists of a protein called opsin that binds a single pigment molecule called retinal.	Point 4
		2. Opsins are membrane proteins that span a membrane multiple times and form a complex with the retinal molecule at the centre (see Figure 1.9, p. 8).	Point 3
		3. This change triggers alterations to the opsin protein, which, in turn, trigger downstream events, including alterations in intracellular ion concentrations and electrical signals.	Point 2
		4. Interestingly, whereas vision and smell are different senses, proteins very similar to opsins are used in olfaction, suggesting that specific aspects of opsin proteins are particularly useful for sensory perception.	Point 2
		5. Recent research has shown that about 200 different proteins are assembled to produce the eyespot apparatus, including specific opsin proteins that are the basis of the rhodopsin-based photoreceptors.	Point 1
retinal	4	1. Each rhodopsin molecule consists of a protein called opsin that binds a single pigment molecule called retinal.	Point 3
		2. Opsins are membrane proteins that span a membrane multiple times and form a complex with the retinal molecule at the centre (see Figure 1.9, p. 8).	Point 2
		3. As shown in Figure 1.9, absorption of a photon of light causes the retinal pigment molecule to change shape.	Point 2
		4. There is a large diversity of pigments, including chlorophyll a, which is involved in photosynthesis; retinal, which is involved in vision; and indigo, which is used to dye jeans their distinctive blue colour.	Point 2
eyespot	9	1. In addition, each cell contains a light sensor called an eyespot that allows individual cells to gather information about the location and intensity of a light source.	Point 4
		2. And the most common photoreceptor in nature is rhodopsin (Figure 1.9, p. 8), which is the basis of	Point 2

		vision in animals but is also very common in other organisms, including C. reinhardtii, where it serves as the light-sensing unit of the eyespot.	
		3. As an example, let's take a closer look at the eyespot of C. reinhardtii.	Point 1
		4. The eyespot is a light-sensitive structure that is approximately 1 μm in diameter and is found within the chloroplast of the cell, in a region closely associated with the cell membrane (Figure 1.10).	Point 4
		5. The eyespot is composed of two layers of carotenoid-rich lipid globules that seem to play a role in focusing and directing incoming light toward the photoreceptors.	Point 3
		6. Recent research has shown that about 200 different proteins are assembled to produce the eyespot apparatus, including specific opsin proteins that are the basis of the rhodopsin-based photoreceptors.	Point 1
		7. Although it is in the chloroplast, the eyespot does not play a role in photosynthesis.	Point 1
		8. Instead the photoreceptors of the eyespot allow the cell to sense light direction and intensity.	Point 3
		9. Light absorption by the eyespot is linked to the swimming response by a signal transduction pathway; light absorption triggers rapid changes in the concentrations of ions, including potassium and calcium, which generate a cascade of electrical events.	Point 2
chloroplast	4	1. The eyespot is a light-sensitive structure that is approximately 1 μm in diameter and is found within the chloroplast of the cell, in a region closely associated with the cell membrane (Figure 1.10).	Point 2
		2. Although it is in the chloroplast, the eyespot does not play a role in photosynthesis.	Point 2
		3. Although the energy of one photon is very small, the photosynthetic apparatus within the chloroplast of a single C. reinhardtii cell absorbs millions of photons each second.	Point 2
		4. And a single cell within a typical plant leaf contains hundreds of chloroplasts!	Point 2
phytochrome	3	1. In plants, a photoreceptor called phytochrome senses the light environment and is critical for photomorphogenesis, the normal developmental process activated when seedlings are exposed to light (Figure 1.11).	Point 3

		2. Phytochrome is present in the cytosol of all plant cells, and when a seedling is exposed to wavelengths of red light, phytochrome becomes active and initiates a signal transduction pathway that reaches the nucleus.	Point 3
Halobacterium	3	1. That is, some organisms do not use the light energy to convert carbon dioxide into carbohydrates. A good example is a genus of organisms within the Archaea called Halobacterium.	Point 4
		2. Species of Halobacterium contain a pigment– protein complex called bacteriorhodopsin, which functions as a light-driven proton pump.	Point 2
		3. As the name suggests, rhodopsin is structurally similar, and evolutionarily related, to the bacteriorhodopsin found in Halobacterium.	Point 1
algae	1	1. These organisms include plants, algae, invertebrates, and even some prokaryotes.	Point 2

Table 6

The description of the pictorial contexts containing the target words from the biological text

(Only the words contained in pictorial contexts are shown in this table).

Target words	Frequency in pictorial contexts	Pictorial contexts containing the target words	The informativeness of the pictorial contexts
eyespot	5	Figure 1.1 (twice)	Point 3
		Figure 1.10 (three times)	Point 2
chloroplast	2	Figure 1.1 (twice)	Point 3
photoreceptor	2	Figure 1.9	Point 2
		Figure 1.11	Point 2
retinal	4	Figure 1.5	Point 1

		Figure 1.8 (twice)	Point 2
		Figure 1.9	Point 3
Halobacterium	3	Figure 1.8 (three times)	Point 3
photon	4	Figure 1.4 (twice)	Point 2
		Figure 1.6 (twice)	Point 2
cellular respiration	2	Figure 1.7 (twice)	Point 3
pigment	6	Figure 1.5 (six times)	Point 2
		Figure 1.6	Point 2
conjugated system	1	Figure 1.5	Point 2
photosynthesis	7	Figure 1.1	Point 2
		Figure 1.3	Point 2
		Figure 1.5	Point 1
		Figure 1.7 (four times)	Point 3
opsin	2	Figure 1.9 (twice)	Point 3
phytochrome	1	Figure 1. 11	Point 3
algae	2	Figure 1.1	Point 2
		Figure 1.5	Point 1

Table 7

The description of the target words from the text of film studies

Target words	Prompt words	Relevance to reading comprehension	Part of speech	Concreteness of target words	The number of words in target items	Definitions of the words	The number of aspects of the meaning senses of target words
sprocket	stick out	relevant	n.	Concrete word	1	*it's an object. It's the one or more rows of tooth-like parts sticking out in a device that pulls film, paper, etc. through a machine at a uniform rate and smoothness	1 meaning sense with 5 or 6 aspects
aperture	open	Relevant	n.	Concrete word	1	*It's an object. It's an opening that allows light to reach a lens in cameras, projectors and printers of film.	1 meaning sense with 4 or 5 aspects
reel	Wind or spiral	relevant	n.	Concrete word	1	*An object or device that is used to hold and release film strips in cameras, projectors and printers of film.	1 meaning sense with 5 aspects

gelatin	substance	relevant	n.	Concrete word	1	˜A clear substance without any taste that is made from boiling animal bones and is used to make jelly, film for cameras, etc.	1 meaning sense with 5 aspects
emulsion	light	relevant	n.	Concrete word	1	*Layers of substances on photographic film or paper that contains chemicals which are sensitive to light	1 meaning sense with 4 aspects
gauge	measure	relevant	n.	Abstract word	1	*It's a dimension or an aspect to describe something. The width of the film strip, measured in millimeters.	1 meaning sense with 3 or 4 aspects
optical	visual	relevant	Adj.	Abstract word	1	˜relating to light	1 meaning sense with 1 aspect
flicker	light	relevant	n./v.	Abstract word	1	1. *An early term for movies	1 meaning sense with 1 aspect
						2. ˜to move with small quick movements or make a sudden movement	1 meaning sense with 4 aspects
celluloid	sheet	irrelevant	n.	Concrete word	1	˜An object A thin transparent plastic material made in sheets. (or film). *It was used in the past for cinema film	1 meaning sense with 5 or 6 aspects
speck	Carrying visual infor-mation	relevant	n.	Abstract word	1	˜A very small spot or a very small amount of something	1 meaning sense with 2 aspects
sensor	feel	relevant	n.	Concrete word	1	˜An object. A device that can react to light, heat, pressure, etc. in order to make a machine, etc. do something or show something	1 meaning sense with 4 or 5 aspects
pixel	Picture	relevant	n.	Abstract wod	1	*A measurement. Short for "picture elements". The small glowing dots that make up the image of a picture; The density of visual information increases proportionately with the number of pixels.	1 meaning sense with 5 or 6 aspects
Perforation	dip	relevant	n.	Concrete word	1	*It's a part of an object. It's the series of small holes in two edges of frim strips	1 meaning sense with 2 or 3 aspects
resolution	clear	relevant	n.	Abstract word	1	*One dimension or aspect to describe a picture: the clearness of image depending on the size of the dots that make up the image (Or the number of pixel of pictures)	1 meaning sense with 2 or 3 aspects
pulsation	Move	relevant	n.	Abstract word	1	˜The fact of making strong regular movements or sounds	1 meaning sense with 3 or 4 aspects

monophonic	sound	relevant	n.	Abstract word	1	˜Something about sound. Recording or producing sound which comes from only one direction	1 meaning sense with 2 or 3 aspects
Stereophoni-c	Sound	relevant	n.	Abstract word	1	˜Something about sound. Recording or producing sound which comes from more than one direction	1 meaning sense with 2 or 3 aspects
encrypt	informatio n	relevant	v.	Abstract word	1	˜A movement. to change electronic information into a secret system of letters, numbers, or symbols	1 meaning sense with 3 or 4 aspects
historical spectacle	heroic	irrelevant	n.	Abstract word	2	˜Epic films, a style of filmmaking, with large scale, sweeping scope, and spectacle, focused on a heroic character	1 meaning sense with 3 aspects

*: The definitions of the words are from the reading materials.

˜: The definitions of the words are from the consultation of learner's dictionaries.

Note: the definitions of target items consist of different aspects. Diverse aspects are written in different colors.

Table 8

The description of the textual contexts containing the target words from the geological text (Only the target words contained in textual contexts are shown in this table)

Target words	Frequency of the target words in textual contexts	Textual contexts containing the target words	Informativeness of the textual contexts containing the target words
sprocket	2	1. The strip is perforated along both edges, so that small teeth (called sprockets) in the machines can seize the perforations (sprocket holes) and pull the film at a uniform rate and smoothness.	Point 4
gelatin	1	1. Motion picture film consists of a transparent plastic base (the shiny side), which supports an emulsion, layers of gelatin containing light-sensitive materials.	Point 1
emulsion	3	1. Motion picture film consists of a transparent plastic base (the shiny side), which supports an emulsion, layers of gelatin containing light-sensitive materials. 2. On a black-and-white film strip, the emulsion contains grains of silver halide.	Point 4 Point 2

		3. Color film emulsion adds layers of chemical dyes that react with the silver halide components.	Point 2
gauge	4	1. So, too, has the width of the film strip, which is called the gauge and is measured in millimeters.	Point 4
		2. For most of cinema history, commercial theaters used 35mm film, but other gauges also have been standardized internationally: Super 8mm, 16mm, and 70mm (1.15–1.19).	Point 3
		3. With the rise of digital filmmaking, 16mm has declined as an amateur gauge.	Point 2
		4. Yet a higher-quality version of the gauge, Super 16mm, still gets used in commercial films seeking to economize or to achieve a "documentary look.”	Point 2
optical	6	1. Most films today have an optical sound track, which encodes sonic information in the form of patches of light and dark running along the frames.	Point 3
		2. When the film is projected, the optical track produces varying intensities of light that are translated back into electrical impulses and then into sound waves	Point 3
		3. The optical sound track of 16mm film is on the right side (1.16), whereas 35mm puts an optical track on the left (1.17, 1.18).	Point 1
		4. The 16mm film strip (1.16) and the first 35mm film strip (1.17) have monophonic optical tracks.	Point 1
		5. Stereophonic optical sound is registered as a pair of squiggles running down the left side (1.18).	Point 1
flicker	5	1. At present, researchers believe that two psychological processes are involved in cinematic motion: critical flicker fusion and apparent motion.	Point 1
		2. This raises the number of flashes to 48, the threshold of what is called critical flicker fusion.	Point 1
		3. The picture had a pronounced flicker—hence an early slang term for movies, "flickers", which survives today when people call a film a "flick".	Point 2
		4. Apparent motion and critical flicker fusion are quirks in our visual system, and technology can exploit those quirks to produce illusions.	Point 1
celluloid	2	1. Film as we know it came into being when photographic images were first imprinted on strips of flexible celluloid.	Point 3
		2. Just as audio books and e-books were still called books, digital films counted as films, even though they never involved light hitting celluloid.	Point 2
speck	1	1. A frame of photographic film holds billions of specks carrying visual information.	Point 3
sensor	6	1. Instead of a strip of film whizzing through a gate behind the lens, the digital camera has a fixed sensor.	Point 1

		2. The sensor is covered with a grid of millions of microscopic diodes, or photosites.	Point 1
		3. The sensor converts these patterns of light into electrical impulses that are sent to a recording medium and registered as files of ones and zeroes.	Point 2
		4. Digital image quality depends on several factors, including the size of the sensor, the number of pixels, and the type of compression applied to the files.	Point 1
		5. Sensors come formatted for these various image sizes.	Point 1
		6. They employ minimal data compression, and they tend to have larger sensors, ones about the same size as a frame of 35mm film.	Point 1
pixel	14	1. The diodes create pixels (short for "picture elements") in the final image.	Point 2
		2. But pixels are much larger than photographic molecules, so making digital imagery as finely detailed as 35mm is a challenge.	Point 1
		3. Digital image quality depends on several factors, including the size of the sensor, the number of pixels, and the type of compression applied to the files.	Point 2
		4. The images were quite low resolution (about 350,000 pixels), but lit by an experienced cinematographer they could be attractive, as in Spike Lee's Bamboozled, shot by Ellen Kuras.	Point 1
		5. The numbers refer to the number of horizontal lines in the display, and "p" stands for progressive scan, which refreshes each frame in the manner of a computer monitor; 720p images contain about 921,000 pixels, and 1080p images have nearly 2.1 million. The numbers refer to the number of horizontal lines in the display, and "p" stands for progressive scan, which refreshes each frame in the manner of a computer monitor; 720p images contain about 921,000 pixels, and 1080p images have nearly 2.1 million.	Point 2
		6. The newer formats, often known as "digital cinema," were standardized at 2K (usually rated at 2,048 pixels across, or about 3.2 million pixels in all) and 4K (4,096 pixels across, or over 12.7 million pixels).	Point 1
		7. The rectangles in Figure 1.23 represent the numbered pixels in each of these formats.	Point 1
		8. The images as projected on a screen would all be the same size, but the density of visual information increases proportionately with the number of pixels.	Point 2
		9. Each format can produce images in different proportions, or aspect ratios, and these make the pixel count vary somewhat. (More on aspect ratios in Chapter 5.)	Point 1

		10. This larger format is 6,144 by 3,160 pixels in size, yielding 2.2 times as many pixels as 4K.	Point 1
perforation	2	1. The strip is perforated along both edges, so that small teeth (called sprockets) in the machines can seize the perforations (sprocket holes) and pull the film at a uniform rate and smoothness.	Point 4
		2. The size and placement of the perforations and the area occupied by the sound track have been standardized around the world.	Point 1
diode	3	1. The sensor is covered with a grid of millions of microscopic diodes, or photosites.	Point 2
		2. Each of these diodes measures a tiny portion of the light.	Point 2
		3. The diodes create pixels (short for "picture elements") in the final image.	Point 2
resolution	4	1. The images were quite low resolution (about 350,000 pixels), but lit by an experienced cinematographer they could be attractive, as in Spike Lee's Bamboozled, shot by Ellen Kuras.	Point 2
		2. Since the information carried on each image increases both vertically and horizontally, each step up multiplies the resolution: 4K carries not twice but four times the amount of information in 2K.	Point 1
		3. Michael Mann's digital camera on Collateral also delivered 2K-resolution images.	Point 2
		4. Prestigious films such as David Fincher's Zodiac and The Social Network showed that high-resolution capture could in many respects rival 35mm film while harboring its own artistic possibilities.	Point 2
pulsation	1	1. During production, electrical impulses from a microphone are translated into pulsations of light, which are photographically inscribed on the moving film strip.	Point 2
monophonic	2	1. A film's sound track may be monophonic or stereophonic.	Point 2
		2. The 16mm film strip (1.16) and the first 35mm film strip (1.17) have monophonic optical tracks.	Point 1
stereophonic	2	1. A film's sound track may be monophonic or stereophonic.	Point 2
		2. Stereophonic optical sound is registered as a pair of squiggles running down the left side (1.18).	Point 1
encrypt	1	1. The DCP, delivered on a hard drive and heavily encrypted, provides a compressed version of the film (1.25).	Point 1

Table 9

The description of the pictorial contexts containing the target words from the text of film studies (Only the words contained in pictorial contexts are shown in this table).

Target words	Frequency in pictorial contexts	Pictorial contexts containing the target words	The informativeness of the pictorial contexts
aperture	4	Figure 1.13 & Figure 1.14	Point 3
reel	4	Figure 1.13 & Figure 1.14	Point 3
sprocket	1	Figure 1.19	Point 2
gauge	4	Figure 1.15 (twicw) Figure 1.17 Figure 1.19	Point 2 Point 2 Point 2
optical	2	Figure 1.17 Figure 1.18	Point 1 Point 1
photon	4	Figure 1.4 (twice) Figure 1.6 (twice)	Point 2 Point 2
pixel	12	Figure 1.22 & Figure 1. 23	Point 2 or Point 1
resolution	1	Figure 1.23	Point 2
historical spectacles	1	Figure 1.19	Point 2
sensor	1	Figure 1.23	Point 1

Table10

The description of the target words from the text of anatomy

Target words	Prompt words	Relevance to reading comprehension	Part of speech	Concreteness of target words	The number of words in target items	Definitions of the words	The number of aspects of the meaning senses of target words
etching	surface	irrelevant	n.	Concrete word	1	˜A movement. Cutting lines on a hard surface to make a picture or words	1 meaning sense with 3 or 4 aspects
cadaver	human	Relevant	n.	Concrete word	1	˜a dead human body	1 meaning

							sense 2 aspects
plastination	technology	relevant	n.	Abstract word	1	*A unique technology that preserves specimens using reactive polymers	1 meaning sense with 3 aspects
physiology	discipline	relevant	n.	Abstract word	1	*The scientific discipline that studies the function of body structures	1 meaning sense with 1 aspects
microscopic anatomy	structure	relevant	n.	Abstract word	2	*It examines structures of human body that cannot be observed by the unaided eye	1 meaning sense with 2 aspects
gross anatomy	big	relevant	n.	Abstract word	2	*Gross anatomy, also called macroscopic anatomy, investigates the structure and relationships of large body parts that are visible to the unaided eye, such as the intestines, stomach, brain, heart, and kidneys.	1 meaning sense with 2 aspects
cytology	small	relevant	n.	Abstract word	1	*A branch of anatomy. A branch of the Microscopic anatomy. It is a study of single body cells and their internal structures	1 meaning sense with 3 or 4 aspects
histology	small	relevant	n.	Abstract word	1	*A branch of anatomy. A branch of the Microscopic anatomy. It's a study of tissues.	1 meaning sense with 2 or 3 aspects
embryology	big	relevant	n.	abstract word	1	*A branch of anatomy. A branch of the gross anatomy. It's a study specially for developmental changes occurring prior to birth.	1 meaning sense with 3 or 4 aspects
pathologic anatomy	big	relevant	n.	Abstract word	2	*A branch of gross anatomy that	1 meaning

						examines all anatomic changes resulting from disease	sense with 3 aspects
radiographic anatomy	big	relevant	n.	Abstract word	2	*A branch of gross anatomy studying the relationships among internal structures that may be visualized by specific scanning procedures, such as ultrasound, magnetic resonance imaging (MRI), or x-ray.	1 meaning sense with 2 aspects
epithelial tissue	surface	relevant	n.	Abstract word	1	*One of four types of tissues that covers exposed surfaces and lines body cavities	1 meaning sense with 3 aspects
metabolism	exchange	relevant	n.	Abstract word	1	*All organisms must exchange nutrients, gases, and wastes with their environment through various chemical reactions	1 meaning sense with 4 aspects
homeostasis	maintain	relevant	n.	Abstract word	1	*A state within bodies of organisms in which control and regulatory mechanisms within bodies maintain a consistent internal environment. A human body maintains homeostasis, or internal equilibrium, through the intricate inter workings of all its organ systems.	1 meaning sense with 3 or 4 aspects
skeletal System	muscle	relevant	n.	Abstract word	2	*One of the 11 organ systems of human body. It provides support and protection, site of hemopoiesis (blood cell production), stores calcium and phosphorus, provides sites for muscle attachments.	1 meaning sense with 6 aspects

integumentary system	temperature	Relevant	n.	Abstract word	2	One of the 11 organ systems of human body. It provides protection, regulates body temperature, site of cutaneous receptors, synthesizes vitamin D, prevents water loss	1 meaning sense with 5 aspects
cardiovascular system	pump	relevant	n.	Abstract word	2	One of the 11 organ systems of human body. It consists of the heart (a pump), blood, and blood vessels; the heart moves blood through blood vessels in order to distribute hormones, nutrients, and gases, and pick up waste products.	1 meaning sense with 7 aspects
urinary system	waste	relevant	n.	Abstract word	2	One of the 11 organ systems of human body. It filters the blood and removes waste products from the blood, concentrates waste products in the form of urine, and expels urine from the body. It involves kidneys, where urine is formed, along with the organs of urine transport (ureters and urethra) and storage (urinary bladder)	1 meaning sense with 8 aspects
small intestine	organ	irrelevant	n.	Concrete word	2	It is an organ of human body. It contains all four types of tissues. It absorbs of nutrients of food.	1 meaning sense with 3 aspects

Note: the definitions of target items consist of different aspects. Diverse aspects are written in different colors.

Table 11

The description of the contexts containing the target words from the text of anatomy (Only the words contained in textual contexts are shown in this table)

Target words	the frequency of the target words in textual contexts	Textual contexts containing the target words	The informativeness of the textual contexts containing the target words
etching	1	1. In the 1700s, the quality of anatomic illustrations improved dramatically with the simultaneous development of etching and engraving techniques along with mezzotint that provided beauty and texture.	Point 2
cadaver	2	1. Anatomists discovered in the early 1800s that cross sections obtained from frozen cadavers and parts of cadavers provided incredible insight into the complexity of the human body.	Point 2
plastination	1	1. Von Hagens is a German anatomist who invented plastination, a unique technology that preserves specimens using reactive polymers.	Point 4
physiology	5	1. Explain how anatomy differs from physiology.	Point 2
		2. The scientific discipline that studies the function of body structures is called physiology.	Point 4
		3. A special relationship exists between anatomy and physiology because structure and function cannot be completely separated.	Point 3
		4. The examples in table 1.1 illustrate the differences and the interrelationships between anatomy (structure) and physiology (function).	Point 3
		5. What is the relationship between anatomy and physiology?	Point 2
microscopic anatomy	6	1. Describe microscopic anatomy and its subdivisions.	Point 1
		2. The discipline of anatomy is an extremely broad field that can be divided into two general categories: microscopic anatomy and gross anatomy.	Point 2
		3. 1.2a Microscopic Anatomy	Point 1
		4. Microscopic anatomy examines structures that cannot be observed by the unaided eye.	Point 4

		5. Specialized subdivisions of microscopic anatomy are defined by the dimensional range of the material being examined.	Point 1
		6. Histology takes a wider approach to microscopic anatomy by examining how groups of specialized cells and their products function for a common purpose.	Point 1
gross anatomy	7	1. Define gross anatomy and compare and contrast its subdisciplines.	Point 1
		2. The discipline of anatomy is an extremely broad field that can be divided into two general categories: microscopic anatomy and gross anatomy.	Point 2
		3. 1.2b Gross Anatomy	Point 1
		4. . Gross anatomy, also called macroscopic anatomy, investigates the structure and relationships of large body parts that are visible to the unaided eye, such as the intestines, stomach, brain, heart, and kidneys.	Point 4
		5. There are several approaches to gross anatomy:....	Point 2
		6. Systemic anatomy studies the gross anatomy of each system in the body.	Point 1
		7. What are some of the subdisciplines of gross anatomy?	Point 1
cytology	1	1. For example, cytology (sı—-tol′ —o-j—e; cyto = cell, logos = study), or cellular anatomy, is the study of single body cells and their internal structures, while histology (his-tol′ —o-j—e; histos = web or tissue, logos = study) is the study of tissues.	Point 4
histology	3	1. For example, in the case of histology, the study of tissues, we give (histos = web, tissue, logos = study).	Point 3
		2. For example, cytology (sı—-tol′ —o-j—e; cyto = cell, logos = study), or cellular anatomy, is the study of single body cells and their internal structures, while histology (his-tol′ —o-j—e; histos = web or tissue, logos = study) is the study of tissues.	Point 3
		3. Histology takes a wider approach to microscopic anatomy by examining how groups of specialized cells and their products function for a common purpose.	Point 4
embryology	2	1. In a second publication, Essays on the Generation of Animals, Harvey established the basis for modern embryology.	Point 1
		2. Embryology (em-br—e-ol′ —o-j—e; embryon = young one) is concerned specifically with developmental changes occurring prior to birth.	Point 4

pathologic anatomy	1	1. Pathologic (path-—o-loj′ -ik; pathos = disease) anatomy examines all anatomic changes resulting from disease.	Point 4
radiographic anatomy	1	1. Radiographic anatomy studies the relationships among internal structures that may be visualized by specific scanning procedures, such as ultrasound, magnetic resonance imaging (MRI), or x-ray.	Point 4
epithelial tissue	2	1. Tissues are precise organizations of similar cells that perform specialized functions. The four types of tissues and their general roles in the human body are (1) epithelial tissue (covers exposed surfaces and lines body cavities); (2) connective tissue (protects, supports, and interconnects body parts and organs); (3) muscle tissue (produces movement); and (4) nervous tissue (conducts impulses for internal communication).	Point 4
		2. Some types of capillary walls also have fenestrations (openings) between the epithelial cells.	Point 2
metabolism	3	1 & 2 Metabolism. All organisms carry out various chemical reactions, collectively termed metabolism.	Point 4
		3. All organisms must exchange nutrients, gases, and wastes with their environment in order to carry on metabolism.	Point 3
homeostasis	3	1. Control and regulatory mechanisms within an organism maintain a consistent internal environment, a state called homeostasis (h—o′ m—e-—o-st—a′ sis; homoios = similar, stasis = standing).	Point 4
		2. For example, when the body temperature rises, more blood is circulated near the surfaces of our limbs and digits (fingers and toes) to facilitate heat loss and a return to homeostasis.	Point 2
		3. Thus, a human body maintains homeostasis, or internal equilibrium, through the intricate interworkings of all its organ systems.	Point 4
urinary system	2	1 & 2 For example, studying the urinary system would involve examining the kidneys, where urine is formed, along with the organs of urine transport (ureters and urethra) and storage (urinary bladder).	Point 4
small intestine	3	1. At the organ level, different tissue types combine to form an organ, such as the small intestine, brain, lungs, stomach, or heart.	Point 2
		2. The small intestine, for example, has different structural and organizational relationships within its tissues that work together to process and absorb digested nutrients.	Point 3

		3. Thus, the small intestine shown in figure 1.3 exhibits all four tissue types: an internal lining composed of simple columnar epithelium; a connective tissue layer that attaches the epithelium to an external layer of smooth muscle; and nervous tissue that innervates the organ.	Point 3

Table 12

The pictorial contexts containing the target words from the text of anatomy (only the target words contained in the pictorial contexts are shown in this table)

Target words	Frequency in pictorial contexts	Pictorial contexts containing the target words	The informativeness of the pictorial contexts
plastination	1	Figure 1.1	Point 2
physiology	2	Table 1.1	Point 3
epithelial tissue	1	Figure 1.3	Point 3
skeletal system	2	Figure 1.4	Point 3
integumentary system	1	Figure 1.4	Point 3
cardiovascular system	1	Figure 1.4	Point 3
urinary system	2	Figure 1.4	Point 3
iymph	8	Figure 1.4	Point 3
small intestine	5	Figure 1.3 Figure 1.4	Point 2 Point 3

2. CV: Yuning Wang

EDUCATION EXPERIENCE

- *09/2015-now* (two-year program) **Faculty of Education, Western University, London, ON, Canada**
  Research focus: incidental learning of second language vocabulary through reading
  Degree: Master of Arts in progress
  Supervisor: Dr. Stuart Webb
  Research courses attended: Introduction to Educational Research, Advanced Quantitative Research Methods, Introduction to Statistics in Education
- *09/2011-07/2015* **School of Foreign Languages, Southwest Jiaotong University (SWJTU), Chengdu, China (**A top university among "211 Project" in China)
  Major: Translation
  Degree: Bachelor of Arts
  GPA: 3.38/4.0

RESEARCH EXPERIENCE

- *09/2015-now* **Pursued M.A. research project, a qualitative study involving interview measures**
  Project name: Incidental learning of L2 technical vocabulary through repeated reading of academic texts Position: associate researcher
  Position: Associate investigator
- *05/2013-04/2014* **Participated in the Student Research Training Program (SRTP) of Southwest Jiaotong University under the supervision of Prof. Meihua Song**
  Project Name: Current Situation and Prospect Forecast of the Cultivation for Translation Majors and English Majors of Southwest Jiaotong University
  Position: Leader of Research Group

WORK EXPERIENCE

12/2016 – present **TED subtitle translator (volunteer)**

07/2017-present **Chinese and Math Instructor for SK students**
London Chinese School, London, Ontario

01/2017-06/2017 **Volunteer TA, ESL class**
GA Wheable Centre for Adult Education, London, Ontario

09/2011-09/2013 **Team Leader, Voluntary Blood Donation Publicity Team,**
Public Service Association, Southwest JiaoTong University