RoLo: A dictionary interface that minimizes extraneous cognitive load of lookup and supports incidental and incremental learning of vocabulary

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ABSTRACT

Dictionary use can improve reading comprehension and incidental vocabulary learning. Nevertheless, great extraneous cognitive load imposed by the search process may reduce or even prevent the improvement. With the help of technology, dictionary users can now instantly access the meaning list of a searched word using a mouse click. However, they must spend great cognitive effort identifying the most appropriate meaning for a given context, contributing to the disruption of the flow of reading and decreasing the positive effect of dictionary use. Furthermore, dictionary users face difficulty in exploiting accumulative illustrations from multiple contexts to understand obscure words whose appropriate meanings are not in the dictionary or are difficult to identify. To address these issues and to offer language learners, especially lifelong learners, effective support for incremental and incidental learning of vocabulary through reading, this research proposes a dictionary interface named RoLo (**R**emind **o**n **Lo**okup). Each time an unfamiliar word is re-looked up, RoLo reminds users about contextual information and word knowledge learned in previous encounters of the word in an appropriate manner. Two studies were conducted to evaluate RoLo. The first study, with 34 participants, examined the effect of RoLo use on incidental vocabulary learning. The second examination, involving 43 participants who used the prototype of RoLo for one month, investigated dictionary users' evaluation of RoLo. The results show that RoLo helps dictionary users enhance vocabulary learning and text comprehension and search for unfamiliar words more easily and faster.

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1. Introduction

One of the best ways to develop vocabulary and improve reading comprehension is frequent reading practice. Especially, reading authentic texts in a foreign or second language (L2) has long been recognized as essential for developing L2 literacy (Gilmore, 2007; Kern, 2003). Thus, with the large variety of authentic reading materials that are available on the Web, reading authentic texts for interesting content is an excellent way to encourage motivated learners to become engaged in real interpretive communication. In addition, reading authentic L2 texts is a frequent activity among individuals who pursue higher education or conduct research. Therefore, the ability to read and comprehend authentic L2 texts efficiently is crucial for all language learners. To successfully comprehend authentic L2 texts, L2 readers must be able to automatically recognize and decode 95%–99% of the words in the texts (Laufer, 1997; Nation, 2001). However, previous studies showed that understanding unknown words in authentic texts presents significant challenges for L2 readers (Groot, 2000), and these readers commonly lack sufficient word knowledge to support successful guessing (Chen, 1998; Grabe & Stoller, 1997). Thus, the likelihood of comprehending authentic L2 texts without the effective semantic support of a dictionary is frustratingly low. In fact, many studies have shown that dictionary use improves reading comprehension (Prichard, 2008). Dictionaries are, therefore, an important learning tool that nearly all L2 readers utilize to facilitate reading comprehension.

In addition to enhancing reading comprehension, dictionary use also improves *incidental vocabulary learning*[1] (Chun & Plass, 1996, 1997; Hulstijn, Hollander, & Greidanus, 1996; Knight, 1994). This is because searching for a word in a dictionary and selecting the correct definition

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[1] "Incidental vocabulary is learnt as a by-product of another activity, such as reading or communication, without the learner's conscious decision, or intention, to learn the words." (Laufer & Hill, 2000, p. 58).

require substantial attention to the target word, and "the more a learner pays attention to a word's morphophonological, orthographic, prosodic, semantic, and pragmatic features and to intraword and interword relations, the more likely it is that the new lexical information will be retained" (Hulstijn, 2001, p. 285). However, if a dictionary imposes excessive cognitive load on its users during the search process, it may reduce learners' attention to the target words, disrupt fluent reading, and discourage learners from searching for unfamiliar words. Nevertheless, not all types of cognitive load imposed by the search process should be avoided. According to Cognitive Load Theory (Sweller, 2005), there are three types of load imposed on a learner's processing, intrinsic, germane, and extraneous cognitive load. Intrinsic cognitive load is due to the innate complexity of the content and is considered unavoidable. Germane cognitive load is due to relevant instructional activities or learning strategies and is considered beneficial to learning. Extraneous cognitive load is due to characteristics of the learning context that are not necessary for learning the content and may even interfere with learning. Thus, to be effective, dictionary interfaces should decrease extraneous cognitive load (such as reading the definitions of irrelevant meanings) and involve an appropriate level of germane cognitive load. In fact, Craik and Lockhart (1972) suggested that retention of information is determined by the manner in which this information is processed.

The advent of electronic dictionaries encouraged research on how these dictionaries are used and their usefulness as learning tools and as contributors to incidental vocabulary learning. Leffa (1992) compared the effect of an electronic dictionary and a paper dictionary on a translation task and found that the electronic dictionary allowed the students to "understand 38% more of the passage, using 50% less time" (p. 63). Recently, Dziemianko (2010) found that compared with paper dictionaries, electronic dictionaries largely enhance both passive recall and active recall of meaning. According to her, this is partly because the visual impact created by an electronic dictionary and the prominent position of a headword on the computer screen attract greater attention than a printed page. These studies suggest that electronic dictionaries are better learning tools than paper dictionaries. Furthermore, with the help of technology, it is possible to design electronic dictionaries with interfaces integrated into the reading environments in which word meanings can be instantly accessed by a mouse click. Examples of these dictionary interfaces include *LiveDictionary*, the *Google dictionary extension* for the Google Chrome browser, and the two dictionary services on the *Ultralingua.net* and *WordCham* websites. These dictionaries display a popup window with word meanings near the word when users point to the word or click/double-click on it. Another example is *MS Word 2007*, which displays a panel with word meanings on the right hand side of the main window when the user presses the Alt key and clicks on the unknown word in the main window. Despite providing instant access to the word meanings, these dictionary interfaces have the following three drawbacks:

First, they do not support *selecting the suitable definition* for a given usage of an unfamiliar word. Rather than placing definitions with a high possibility of being selected at the top of the meaning list, current dictionaries display all meaning definitions or translations in the *same order* for all user searches. This is improper because of the following reasons: 1) Dictionary users often stop reading the entry for a word after reading only the top few definitions, irrespective of whether they provide the correct definition for the given usage of the word (Bogaards, 1998; Kulkarni, Heilman, Eskenazi, & Callan, 2008). 2) The process of understanding a meaning definition or translation and then evaluating whether it fits the current context requires some cognitive load. Doing this many times for irrelevant meanings not only increases extraneous cognitive load and impedes the flow of reading, but also discourages users from searching for unknown words, which in turn may negatively affect text comprehension. Furthermore, increasing extraneous cognitive load reduces attention to the correct meaning and thus reduces incidental learning of this meaning. 3) Dictionary users look up a word not only to find an unknown meaning, but also to recall a forgotten meaning. Displaying all possible meanings of the word in the same way makes it difficult for dictionary users to identify the forgotten meaning found during previous searches for the word. 4) Different dictionary users may search for different meanings of the same word. Furthermore, a single user often works with only one particular meaning of a word during a certain period of time.

Second, current dictionaries do not support L2 readers to incrementally learn unfamiliar words through accumulated illustrations from multiple encountered contexts. Dictionary information is not always sufficient for learners to understand unfamiliar words in authentic texts. To understand a difficult word feature (e.g., meanings of specialized terms or obscure words) or to have a deep understanding of a word, learners must not only read the entry of dictionaries, but also observe accumulated illustrations from different encountered contexts. Furthermore, word learning is an incremental process (Nation, 2001). Acquiring a word is not simply the act of connecting a word form to word meaning, but a complex process that involves the learning of grammatical functions such as parts of speech, sociolinguistics factors such as word connotation, and frequency intuitions such as collocation over the course of multiple encounters of the target word in diverse contexts (Nation, 1990, 2001). Each time L2 readers encounter an unknown word, they learn some word knowledge from the context and/or dictionary information. However, this knowledge gain is incomplete and easy to forget. Besides, in real life, the interval between illustrative encounters (i.e., encounters whose contexts illustrate some word features) is often large enough for learners to forget the word knowledge that was learned during previous encounters. This causes difficulties in accumulating knowledge from multiple encounters to gradually form a complete understanding of the word. Thus, dictionary interfaces should support users in understanding unfamiliar words on the basis of not only dictionary information, but also accumulated illustrations from multiple illustrative and relevant contexts.

Third, current dictionaries do not support *making, testing and developing a hypothesis* about word meaning. In many cases, such as when facing obscure words or domain-specific terms or in contexts with many unknown words, users cannot choose the suitable meaning, even with substantial effort. Current dictionaries do not provide an effective storing–retrieving mechanism that stores the current context together with the temporary result of inferring word meaning from the context, such as a hypothesis about the word's general meaning, to retrieve and develop in the future. Thus, when re-encountering the word in an illustrative context, current dictionary users lose their work results (e.g., hypothesized meanings) from previous encounters. The incremental learning process based on a series of formulating, testing and developing hypothesis about word meaning on the basis of illustrations from encountered contexts must be supported because previous research studies showed that "meaning inferred" yields higher retention than "meaning given" (Hulstijn, 1992; Mondria & Boer, 1991). Moreover, the generative models (e.g., Wittrock, 1974) claim that learning and retention are improved when learners create connections between old and new knowledge by using, reformulating and elaborating the new information. Many lexical studies have confirmed that increased generative processing results in increased word gain (Joe, 1995, 1998; Zaki & Ellis, 1999).

In the current research, we aim to propose and evaluate a dictionary interface, named *RoLo (**R**emind **o**n **L**ookup)*. This interface not only addresses the above issues, but also offers language learners, especially lifelong learners, effective support for incremental and incidental learning of vocabulary through reading. RoLo reminds its users about word knowledge (e.g., hypothesized meanings, knowledge illustrated by encountered contexts, etc.) and contextual information (location, date) from previous encounters of a word in an appropriate manner (see Section 2.2.2) when that word is searched again (hereafter, re-looked up). This behavior is similar to the way humans answer questions previously

asked. When we answer a question that was previously asked and answered, we tend to remind the questioner about where and when the question was asked. Dumais et al. (2003) suggested that people often rely on contextual cues such as time and author to retrieve information that was previously encountered. To reduce the cognitive load required by selecting the appropriate meaning during a search, RoLo places the most recently encountered meaning of a word at the top of the word's meaning list. This behavior is based on the phenomenon that when a meaning is chosen during a search for a word, it is quite likely that the same meaning will be chosen during the next search for that word. This phenomenon is due to the re-access pattern, forgetting, and the limiting nature of lexicon. An example of re-access pattern has been observed (Catledge & Pitkow, 1995; McKenzie & Cockburn, 2001; Tauscher & Greenberg, 1997), as 58–81% of Web pages accessed were re-visits to previously viewed pages. Similar re-access patterns have been observed in the usage of Unix commands (Greenberg, 1993), library book borrowing (Burrell, 1980), human memory (Anderson & Schooler, 1991), and computer memory reference (Patterson & Hennessy, 2005, p. 468). When reading texts that cover a particular field, it is quite likely that different appearances of a word in the same or different texts have the same meaning. In this case, dictionary searches for that word, except the first search, are re-lookups. Another form of re-lookup occurs when dictionary users perform searches for different morphological forms of the same word when they do not know that the forms are indeed of a single word.

2. System design

2.1. System architecture

The system is designed based on the *MVC architecture pattern*[2] and can be logically divided into the following six components: the Interface component, the Controller component, and four database components, which include Dictionary, Extra-meanings, Morphological forms, and Historical information (see Fig. 1).

The Dictionary component stores all dictionary information, which, in our implementation, can be either the WordNet database from Princeton University (http://wordnet.princeton.edu) or Excel files whose content is manually entered. The version of RoLo that uses the WordNet database (hereafter, full version) is thus a monolingual dictionary. The version using dictionary information in Excel files (hereafter, simplified version) can be either a monolingual or bilingual dictionary, depending on whether the word explanation in the Excel file is in L2 or in the first language (L1). For the first study in this research (see Section 3.1), we provided Excel files containing word explanation in Vietnamese and in Chinese, and the simplified version could work in either English–Vietnamese (E–V) or English–Chinese (E–C) mode (see Fig. 3).

The Extra-meanings component is used to store special meanings that do not exist in the Dictionary component and are encountered while reading. The Morphological forms component contains all morphological forms of all words. This research uses *DictGet* (Zamora, 2006), a free dictionary, for this component. The Historical information component contains all information about the user's lookup behavior and the context information of every search.

The Interface component, integrated into the reading environment, captures the word to look up when the user double-clicks on it, and then sends the word to the Controller component. The Controller component, in turn, collects necessary information from the database components and determines which type of information it should send to the Interface component for display and which information it should store to the database components.

2.2. Interface design

2.2.1. Information presentation

The interface of RoLo consists of two types of popup windows, which can be popped up or removed by a click or double-click. Each popup has an independent scroll bar, which automatically appears or disappears according to the length of the content of the popup.

1) *Meaning popup*. This is the popup window that contains word meanings. It consists of, at most, the following three sections, distinguished by their colors (in the web version) (see Fig. 2):
   - The *Violet* section – meaning definitions or translations that were chosen during previous lookups are displayed in violet color.
   - The *Blue* section – hypothesized meanings typed by the user during previous lookups are displayed in blue color.
   - The *Black* section – meaning definitions or translations, from the Dictionary database, that were not previously chosen are displayed in black color.

The three sections are arranged in the popup from top to bottom in the following order: the Violet, the Blue, and the Black section. Each of the three sections is not always displayed. For example, the first time that a word is searched, the meaning popup only displays the Black section. Conversely, if all meanings of a word were previously chosen, then the meaning popup for this word does not include the Black section. At the bottom of the popup, there is an edit box for the user to type hypothesized meanings (when no meaning from the dictionary is suitable for the context). Below the edit box, a small button is displayed with a question symbol. The function of this button is described in Section 2.2.2.

2) *Context sentence popup* (*CS popup*). This popup window contains the context sentences from previous encounters of a word (see Fig. 3). For each context sentence, there are two corresponding buttons, the Source button and the Delete button (labeled with the 'x' character). The Source button is used to open the Web page that contains the context sentence(s) (if the word is encountered on the Web). The word in the context sentences and the context sentence(s) in the web page (if any) are highlighted. The Delete button is used to delete a context sentence from the list of context sentences corresponding to a meaning. The user can change the association between a meaning and a context sentence by clicking on the Delete button corresponding to the context sentence and then clicking on another meaning for the context sentence (Figs. 4 and 5).

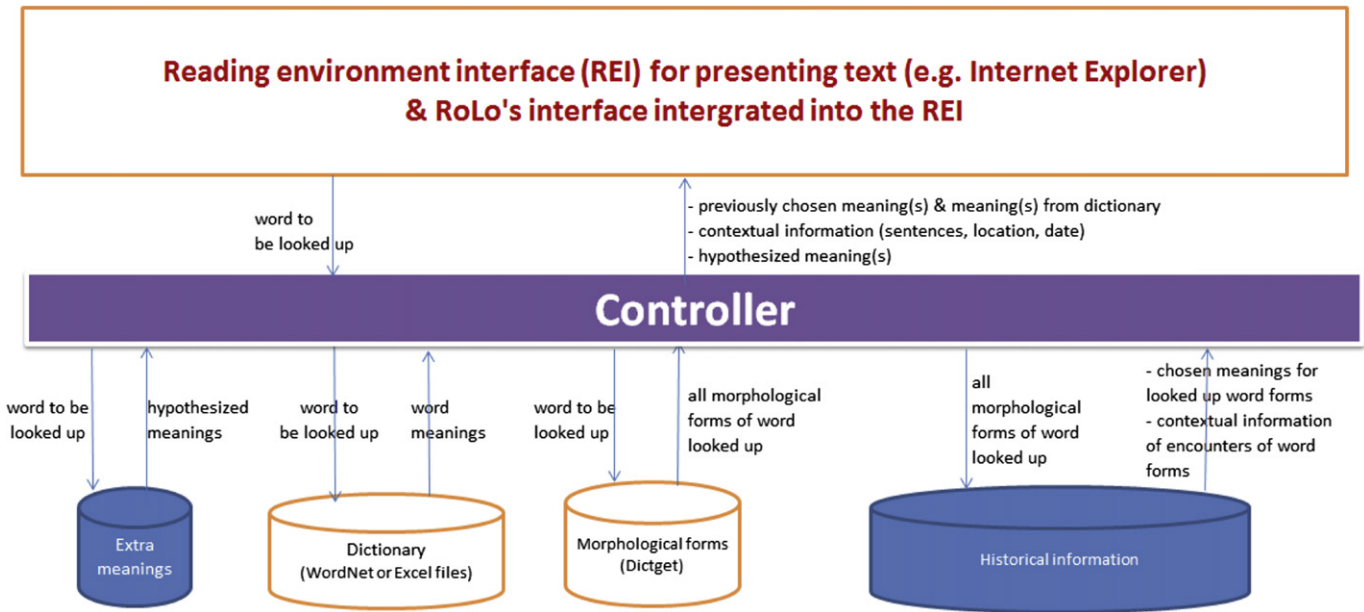[2] For details about the MVC pattern, see (Sommerville, 2010).

Fig. 1. Architecture of RoLo.

2.2.2. Interaction

When a user double-clicks on an unfamiliar word to look it up, RoLo responds according to the previous search behavior of the user. There are two cases:

1) If the word has not been previously encountered, all of its meanings from the Dictionary database are presented in the Black section of the meaning popup. If the appropriate meaning is determined, the user clicks on the definition or translation representing that meaning; then the word form and the selected meaning are stored in the Historical database. If the word's meaning cannot be determined and hypothesized, the user clicks on the question symbol; then the word form and contextual information are stored in the Historical database, with a question symbol stored in the meaning field of the word. This indicates that this context sentence and word form must be considered in future illustrative contexts to achieve a greater understanding of the word. If the user has a hypothesis about the word meaning, the user types the hypothesized meaning into the edit box to store it in the Extra-meanings database.

2) If the word has been encountered, the Interface component displays the meanings that were previously selected by the user and the corresponding word forms in the Violet section of the meaning popup. The meanings and forms in the Violet section are sorted by the time that they were selected, with the most recently chosen meaning at the top of the popup. Similarly, the meanings and forms in the Blue section are sorted by the time that they were hypothesized, with the most recently hypothesized or edited meaning at the top of this section. The user can press the Alt key and at the same time click on a previously chosen or hypothesized meaning to view a list of old context sentences in the CS popup, which appears next to the meaning popup (see Fig. 3). The sentences in the CS popup are grouped and sorted by encounter date, with the most recently encountered sentence at the top of the popup. Moreover, if the mouse pointer hovers over the Source button, RoLo displays the URL of the Web page in which the word was encountered. In this way, the user can
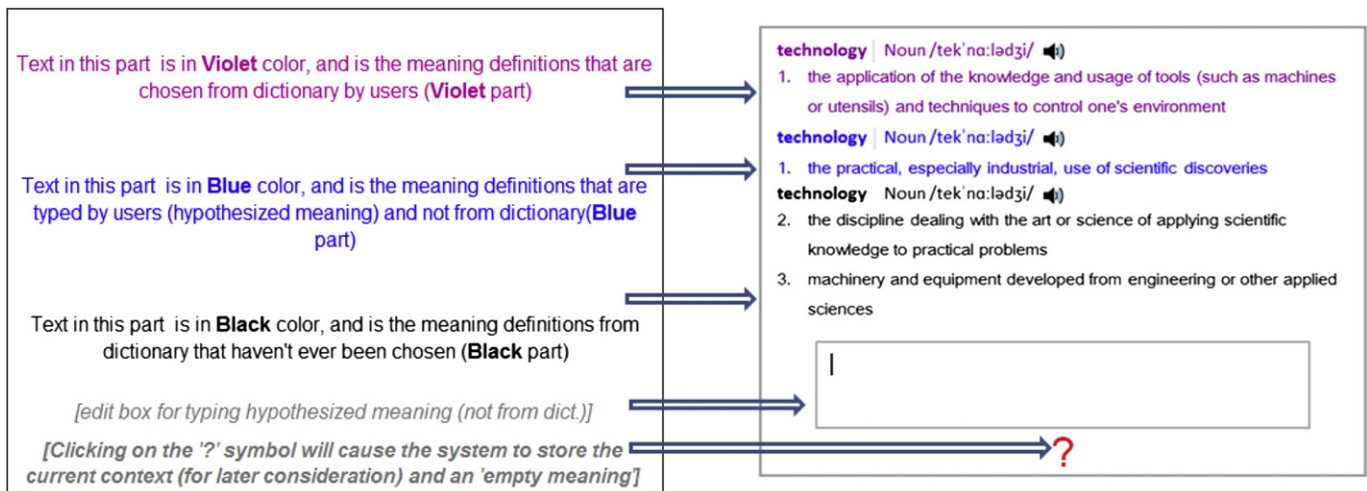

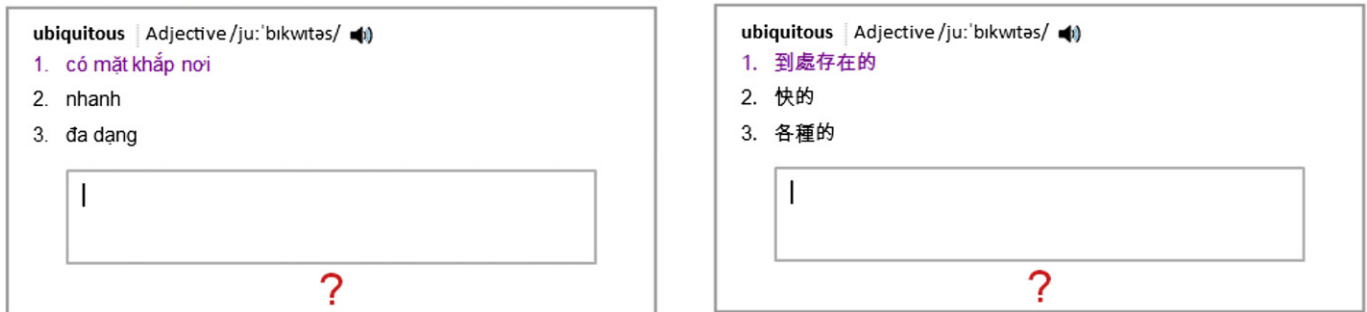**Fig. 2.** The meaning popup of the full version (right side).

Fig. 3. Meaning popups for the E–V (left side) and E–C (right side) modes of the simplified version.

easily know where the word was encountered. The user may find useful information from the URL (e.g., http://llt.msu.edu/vol1num1/chun_plass) such as organization and author, which can be used as clues for recalling the word. The URL is automatically stored when the user double-clicks on a word in a Web page to look it up (in this case, the Interface component is integrated into a Web browser, such as the RoLo prototype). The user can also double-click on an unknown word in the CS or meaning popup to search for it. Clicking outside of a popup causes it to disappear. (in the web version)

3. Evaluation

To evaluate the efficacy of RoLo, two studies were conducted. The first study, described in Section 3.1, aimed to answer the question of *how RoLo use influences incidental vocabulary learning*. The second study, described in Section 3.2, investigated *how dictionary users evaluate RoLo*. The simplified version was examined in the first study, and the full version was used in the second study. Both versions had interfaces that were integrated into Internet Explorer (IE) so that the participants could use RoLo when reading English texts on the Web.

3.1. Evaluation of the effect of RoLo on incidental vocabulary learning

3.1.1. Reading materials

This experiment used two short texts (see Appendix) for two reading tasks. To create the texts, we first selected a list of fifteen words that appeared in a passage extracted from "Meeting Mania" (Bergman, 1994). We then asked 20 students who were not involved in the experiment to mark the words in the list that were unfamiliar to them. The ten words that most of the students marked as unfamiliar were selected as the target words to be investigated in this experiment. Then, we created the first text (110 words) by editing the abovementioned passage so that it would not cause any difficulty for the participants except for the target words (e.g., simplifying sentence structures, replacing the low-frequency non-target words with their high-frequency synonyms).

The second text (122 words) was written using the target words and high-frequency words. The meaning of each target word was held constant in both texts. However, of the ten target words, only five maintained the same morphological forms in both texts (hereafter, SF words); the form of the other five words was altered in the second text (hereafter, CF words). Table 1 lists the target words' forms in the texts.

3.1.2. Participants

Initially, 50 English-as-a-Foreign-Language (EFL) graduate students, who were non-English majors, participated in the experiment. The data of only 34 students were included in the data analysis, as explained in Section 3.1.5. Of the 34 students, 26 were Taiwanese and 8 were
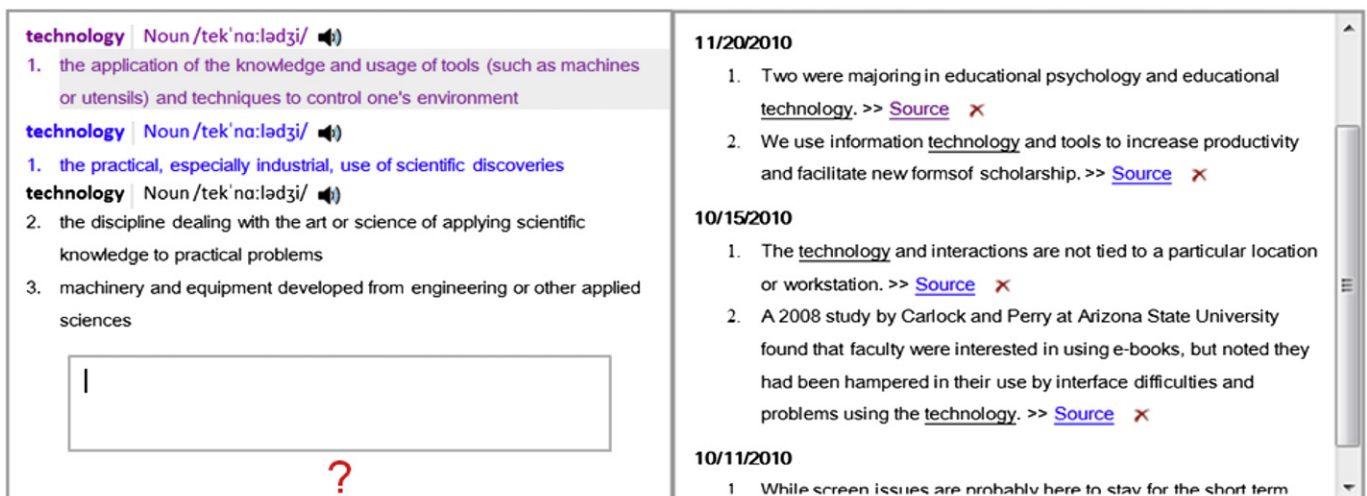

Fig. 4. Meaning popup (left side) & CS popup (right side) of the full version.
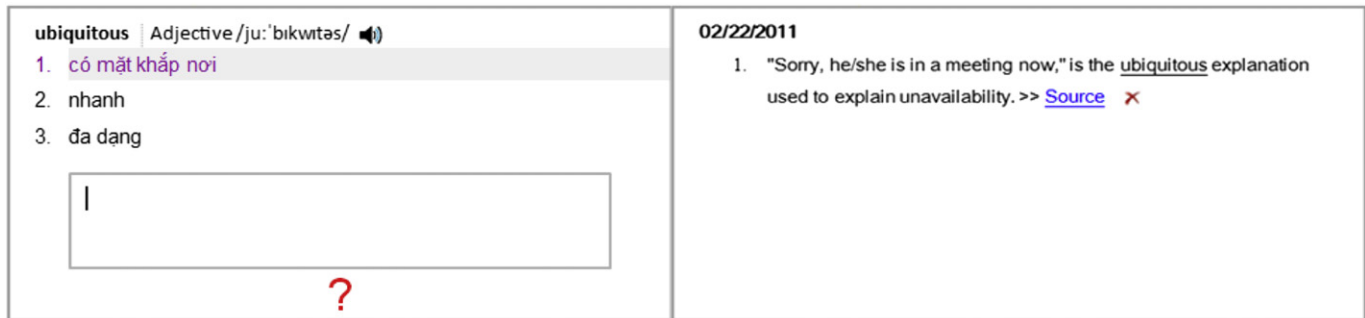
Fig. 5. Meaning popup (left side) & CS popup (right side) of the simplified version (E–V mode).

Vietnamese. All participants had been learning English for at least ten years before graduating and often read articles in English. They were able to read the texts without any difficulty except for the target words.

3.1.3. The software

The subjects read the texts using the simplified version of RoLo. This version provides L1 translations of only the non-trivial words (i.e., words other than function words such as 'have', 'the', 'a' and question words such as 'who', 'what') in the texts. The L1 translations in the two modes were semantically similar. To keep the cognitive load imposed by the search process similar for all target words, each of these words was provided with a list of exactly three L1 translations, of which only one was correct but the other two also made sense in the context (i.e., they did not sound strange in the context and grammatically fit the context). For most of the target words, the correct translations were initially placed at the last position of the lists. To prevent the participants from guessing the correct translations' position, the correct translations of two target words (*malpractice* and *rampant*) were initially placed at the second position of their three-translation lists. Of note, due to the reminding feature (see Section 2.2.2), the position of a word's correct translation in the meaning popup can change. When, for example, double-clicking on the target word *ubiquitous* in the text, the corresponding meaning popup contained the three translations of 快的, 各種的, and 到處存在的 for the Taiwanese participants and of "nhanh", "đa dạng", and "có mặt khắp nơi" for the Vietnamese participants. However, when double-clicking on a non-trivial word other than the target words, the meaning popup contained only the correct translation. Thus, the cognitive load required by the reading process was comparable for all subjects. That is, the load imposed on a participant who did not know the target words and some non-target words and that imposed on a participant who only did not know the target words was comparable. It is worth noting that the non-target words in the texts were high-frequency words, meaning that all of the participants would likely know them. Because the design of this study required the participants to choose the correct translations from the three-translation lists, we disabled the edit box and the Question button in the meaning popup during the experiment.

3.1.4. Procedure

The experimental procedure consisted of two sessions. The second session occurred one week after the first session.

3.1.4.1. The first session.
This session included the following four stages: pre-test, instruction, reading, and recall protocol.

3.1.4.1.1. Pre-test and instruction.
The pre-test allowed us to determine whether some of the target words were familiar. Each subject received a paper test sheet with ten target words. They were directed to write, in either English or L1, the meanings of the words that they knew next to the words. After completing the pre-test, participants were instructed in the use of RoLo. Because interaction with RoLo is quite simple, all participants used RoLo without any difficulty after approximately 10 min of instruction and practice.

3.1.4.1.2. Reading and recall protocol.
When all of the subjects were familiar with the use of RoLo, they began to read the first text displayed on RoLo's interface. They were instructed to read and understand the text in order to complete the recall protocol later. They were also asked to click on the searched word's L1 translation that they considered suitable for the context. During the reading process, RoLo logged every lookup behavior of the subjects. After completing the reading task, the participants were asked to write the propositions that they could remember in L1.

3.1.4.2. The second session.
Of the 50 participants, only 34 searched for all ten target words during the reading task in the first session and did not provide a correct answer in the pre-test. These individuals were asked to participate in the second session, which consisted of the following four activities: re-instruction, reading, vocabulary test, and recall protocol.

3.1.4.2.1. Re-instruction and reading.
For approximately 5 min, subjects were re-instructed on the use of RoLo. Then, they were asked to carefully read the second text displayed on RoLo's interface to complete a recall protocol after reading it. They were not notified of the

Table 1
List of target words with their morphological forms in the two texts.

CF words' forms in text 1	CF words' forms in text 2	SF words' forms in both texts
burgeoning	burgeon	malpractice
scrutiny	scrutinizing	insidious
profusion	profuse	pervasive
ubiquitous	ubiquity	congregate
rampant	rampancy	mania

vocabulary test that would follow. The subjects were also asked to click on the L1 translation that they considered suitable for the context when they searched for an unfamiliar word. Before performing the reading task, the 34 subjects were randomly divided into two groups of seventeen, the treatment group and the control group. While reading the text on RoLo's interface, the reminding feature (see Section 2.2.2) was only available to the treatment group. All other features of RoLo were available to both groups. RoLo logged every lookup behavior of the subjects while reading.

3.1.4.2.2. Vocabulary test and recall protocol. Upon completion of the reading task, subjects were administered an unexpected vocabulary post-test (on paper) in which the target words' forms that appeared in the first text were listed. The subjects were asked to record the meanings of the words in L1 or English. After the test, they were asked to write the propositions that they could remember.

3.1.5. Data analysis

Only subjects who did not know the target words and searched for all of the words during both reading tasks were selected for data analysis. The log files and the pre-test results showed that all of the 34 subjects who participated in the second session did not know the target words and searched for all of the words during both reading tasks (see Section 3.1.4.2). Thus, they were selected for data analysis. Only the vocabulary-test scores were analyzed; the data from the two recall protocols were ignored. The scoring procedure is straightforward. A correct answer received one point and an incorrect answer received zero points. An answer was considered correct if it correctly expressed the meaning used by the texts.

3.1.6. Results

Two independent samples *t*-tests were used to examine whether the treatment group outperformed the control group on the number of SF words and CF words recalled.

As shown in Table 2, there was a significant difference between the means of the two groups ($t = -4.825$, $p < .001$), indicating that the treatment group recalled more CF words than did the control group.

Similarly, Table 3 shows that the treatment group recalled significantly more SF words than did the control group ($t = -3.77$, $p < .005$).

Eta-squared values calculated from Table 2 and Table 3 were $\eta_1^2 = 42.1\%$ and $\eta_2^2 = 30.8\%$, respectively. This indicates that the reminding feature was more helpful when a target word's different forms were encountered compared to when only one form of that word was encountered.

3.2. Subjective evaluation of RoLo

In the second study, forty-three EFL students used the full version of RoLo for one month. We used log files and a questionnaire to investigate the students' subjective evaluation of RoLo. The students came from a variety of backgrounds, including computer science, civil engineering, English linguistics, economics, and philosophy, and none of them participated in the first study. They often read and browsed online specialized articles and news in English and often used at least two of the dictionaries mentioned in the Introduction section. During the time of study, all participant interactions with RoLo were logged. Especially, for each participant, RoLo logged the number of times unfamiliar words were re-looked up and the number of times old contexts were referred (by pressing the Alt key and clicking on a meaning previously chosen or hypothesized). These numbers helped us determine whether each student used RoLo's features. Table 4 shows that all of the students experienced the features of RoLo.

After one month of use, a questionnaire of thirteen items, designed on a 5-point scale in the Likert format, was delivered to the students. The questionnaire focused on the participants' perceptions of the ease and speed of re-lookups and the effectiveness of the support for understanding unfamiliar words, reading comprehension, and vocabulary retention. The scores for the first ten items of the questionnaire are provided in Table 5. The Cronbach's alpha value of the ten items was .87.

3.3. Discussion

3.3.1. RoLo and incidental vocabulary learning

The results from the first study demonstrated that the use of RoLo improved incidental learning of the target words. There are several possible explanations for this improvement. Highlighting a word's forms and meanings chosen beforehand (as mentioned in Section 2.2.2) may direct users' attention to the lexical information of the word, which in turn may contribute to incidental acquisition of the word. In addition, knowing that the word was previously encountered may encourage users to attend to the lexical information more seriously and thus improve word learning. Another contributing factor to the improvement may be the smaller cognitive load devoted to identifying the most appropriate meaning when re-looking up an unfamiliar word. Because the most recently chosen meaning is placed at the top of the meaning popup and displayed in a special color, users can easily recognize it and do not need to read definitions of irrelevant meanings. Thus, the treatment group was not distracted, or even annoyed, by the irrelevant meanings' definitions and therefore could focus more cognitive resources on the target meaning. As a result, the treatment group recalled the meaning better than did the control group.

The results from the first study also suggest that the reminding feature is more helpful when different morphological forms of a word are searched than when the same morphological form of a word is searched many times. One possible explanation for this extra help is that when encountering multiple morphological forms, without the reminding feature, it may be quite difficult to know that these forms are

Table 2
Descriptive statistics and independent sample *t*-test of number of CF words recalled.

Group	N	Mean	Standard deviation	*t*-Test for equality of means[a]
Control	17	1.059	1.029	$t = -4.825$, Sig. (2-tailed) $= .000$
Treatment	17	2.765	1.032	

[a] Equal variances assumed.

Table 3
Descriptive statistics and independent sample *t*-test of number of SF words recalled.

Group	N	Mean	Standard deviation	*t*-Test for equality of means[a]
Control	17	2.294	.772	$t = -3.774$, Sig. (2-tailed) = .001
Treatment	17	3.353	.862	

[a] Equal variances assumed.

indeed of the same word, especially when the interval between two encounters of the word is large (e.g., one week, as in the experiment). Thus, the control group might not know that they encountered the same word two times in different forms in the two texts, which resulted in a loss of the accumulative effect of multiple encounters on word retention. In contrast, with the help of RoLo, the treatment group knew that the morphological forms encountered in the two texts were of the same word. This information might have increased their interest in paying attention to the two forms or encouraged them to determine the difference between the forms. Paying greater attention to different forms of a single word increases the retention of that word because "multiplicity of lexical information tends to be associated with better retention" (Laufer & Hill, 2000, p. 72). Moreover, determining the difference between the word forms may lead to deeper processing of the lexical information, which in turn could result in better retention (Craik & Lockhart, 1972).

Of note, all of the subjects chose the correct meanings for all searched words during both reading tasks. Thus, the conclusion drawn from the first study about the effect of RoLo on incidental learning of a word only informs cases in which the word's appropriate meaning are correctly chosen during all searches for the word. Further research is needed to investigate the effect of RoLo on retention of a correct meaning when users choose incorrect meanings during several searches. However, we speculate that even if users choose wrong meanings during several searches, the effect of RoLo on incidental vocabulary learning is positive due to RoLo's reminding feature. Each time a word is re-looked up, RoLo reminds users about the word's old contexts and the meanings previously evaluated as suitable for those contexts. Through this mechanism, RoLo offers users chances to re-evaluate the previously chosen meanings on the basis of accumulative illustrations from the old contexts. Thus, in the long run, users can recognize and learn from their mistakes, thereby reinforcing the retention of the word.

Another contribution of RoLo use to incidental vocabulary learning is the contextual clues associated with an unfamiliar word. A majority (90.7%) of the participants in the second study agreed that contextual information that RoLo reminds them about helps them remember unfamiliar words better (Question 9). Furthermore, with the reminding feature, longer RoLo use results in increased familiarity with the illustrative contexts and more contextual clues associated with the searched words. Thus, over the long term RoLo incrementally enhances incidental vocabulary learning. Therefore, RoLo especially benefits lifelong learners in learning vocabulary incidentally, as confirmed by responses to Question 8 and Question 10 (see Table 5).

3.3.2. The ease and speed of re-lookup and L2 reading performance

RoLo is designed to exploit the re-access pattern (see the Introduction Section) to reduce extraneous cognitive load imposed by the search process. Because a previously encountered meaning is likely to be accessed again, displaying the most recently encountered meaning of the searched word at the top of the meaning list increases the chance of a successful first attempt to evaluate whether the meaning fits the word's current context. This reduces the number of times users must read and understand definitions of irrelevant meanings. As a result, the extraneous cognitive load imposed by the search process decreases. In addition, displaying the definitions of encountered meanings in a special color helps users easily recognize and recall them, saving a significant effort for users who recognize the appearances of a word but have forgotten the meaning. Strongly positive responses to Question 1 confirm that this method helps users re-look up unfamiliar words more easily and faster. Furthermore, a majority (93.02%) of the participants agreed that the ability to easily access a word's previous illustrative contexts while re-looking it up enables them to more easily decide which meaning of the word best fits the current context (Question 2). The ease and speed of the RoLo search reduce the disruption of the flow of reading and, as suggested by 88.37% of responses to Question 3, encourage users to re-look up an unfamiliar word when re-encountering it and forgetting its meaning. When an unfamiliar word's meaning is not remembered and is difficult to infer, searching for it each time it is re-encountered not only increases the chance of acquiring the word, but also contributes to more fluent reading (Laufer & Hill, 2000). Of the participants, 83.72% agreed that RoLo helps enhance reading comprehension (Question 4).

One may argue that clicking on a meaning to choose it when searching for a word may increase the cognitive load necessary for the search process. However, responses to Question 5 do not support this position. Moreover, we postulate that clicking on a meaning to explicitly choose it, which makes the search process more interactive, increases user involvement in processing the lexical information or attention to the meaning, and thus contributes to better retention of the meaning.

3.3.3. RoLo and incremental learning of vocabulary

Vocabulary learning is an incremental process in which the features of a word are learned through repeated encounters of the word in diverse contexts. Because each context illustrates only some features of the word, learners must access the accumulated illustrations from many contexts to form the complete understanding of the word. Of the participants, 79.07% agreed that the ability to easily access a word's old contexts when re-looking it up helps them easily combine word knowledge embedded in those contexts with that embedded in the current context to achieve a better understanding of the word (Question 6). This suggests that RoLo helps users incrementally learn

Table 4
Descriptive statistics for referring to old context sentences and re-lookup during one month.

	Mean	Min	Max	SD
Times of re-lookup	16	6	33	7.67
Times of referring to old contexts	4.1	2	7	1.36

Table 5
Subset of questionnaire items and the scores ($N = 43$; Cronbach's alpha = .87).

Question no.	Question	Mean	Agree (%)	Neutral (%)	Disagree (%)
1	Re-looking up an unknown word with RoLo is significantly easier and faster than with a conventional dictionary.	4.6	100	0	0
2	When re-looking up a word with RoLo, I can easily access the word's old illustrative contexts, and thus can more easily decide which meaning of the word best fits the current context.	4.4	93.02	6.98	0
3	I re-look up re-encountered unfamiliar words whose meanings are forgotten more often when using RoLo than when using a conventional dictionary.	4.2	88.37	11.63	0
4	RoLo helps me read English texts faster and understand English texts better.	4.2	83.72	6.98	9.3
5	Clicking on a meaning to explicitly choose it when looking up a word does not produce any difficulty or disruption of the flow of reading.	4.6	97.67	2.33	0
6	When re-looking up a word with RoLo, I can easily access the word's old contexts, and thus can easily combine the knowledge embedded in those contexts with the knowledge illustrated by the current context to understand the word better.	4.1	79.07	16.28	4.65
7	With RoLo, I can easily edit, store, and retrieve hypothesized meanings during lookup, and thus can incrementally infer the meaning that is not in the dictionary of a difficult word or specialized term.	4.4	88.37	11.63	0
8	The longer I use a dictionary like RoLo, the more effective I learn vocabulary incidentally.	4.4	95.35	4.65	0
9	Reminding me about the contextual information associated with a word, like the way RoLo does, helps me remember the word better.	4.4	90.7	9.3	0
10	I will use a dictionary like RoLo for a long time.	4.4	97.67	2.33	0

unfamiliar words over multiple exposures to the words. Moreover, each time a word is re-looked up, the reminding feature helps users incrementally reinforce the retention of the word's old contexts, thereby incrementally reinforcing the retention of the word. Furthermore, as suggested by the responses to Question 7, the feature of storing and retrieving hypothesized meanings of RoLo helps users incrementally infer the meaning that is not in the dictionary database of a difficult word or specialized term. Thus, responses to Question 6 and Question 7 suggest that RoLo supports incremental learning of vocabulary.

4. Conclusion

This research proposes and evaluates RoLo, a dictionary interface that reminds users about meaning choices, contextual information, and hypothesized meanings (if any) from previous searches for an unfamiliar word each time the word is searched. The results from the studies in this research show that RoLo improves not only incidental vocabulary learning, but also the ease and speed of re-lookup. Compared to conventional dictionaries, RoLo provides more effective support for understanding unfamiliar words and comprehending L2 texts. In addition, RoLo assists the incremental learning of unfamiliar words and thus fits the incremental nature of the vocabulary learning process. By allowing its users to easily store and retrieve hypothesized meanings and old contexts during searches, RoLo scaffolds the users along the incremental process of inferring the meaning of an obscure word from multiple contexts. With RoLo, users can take advantage of their familiarity with old contexts and the accumulation of efforts made during previous encounters of an unfamiliar word to reduce the effort needed to determine the meaning of the word when re-encountering it. Longer RoLo use is associated with greater understanding and recall of unfamiliar words and their old illustrative contexts. RoLo, therefore, especially benefits lifelong learners and encourages long-term use of this dictionary.

Of note, there were some limitations to the studies that might lessen the external validity of the research. First, the target population of the studies just consisted of EFL students. Second, the sample of the survey was quite small. Thus, the findings should be considered with caution, especially when extrapolating the results to other population of dictionary users such as native speakers. Further studies with larger samples of participants taken from a wider, more varied population of dictionary users would be needed to generalize the findings to a larger target population.

With the ubiquity, important role, and numerous users of dictionaries, the benefits offered by the proposed interface have a significant meaning. Thus, the guidelines drawn from this research are valuable to the development of dictionaries for language learners.

We are continuing to further develop RoLo in several directions. One area for improvement is support in searching for phrases and idioms. Another area is the integration of RoLo into other reading environments, such as Acrobat Reader, MS Word, etc. Finally, we would like to support searching not only dictionary databases, but also the Web for lexical information.

Appendix

Text 1

*Meeting **Mania***

Because of the health care reform being performed by the government, the **burgeoning** costs of the nonclinical aspects of patient care are finally coming under **scrutiny**. Most of the focus is properly being directed toward paperwork, **malpractice**, and unnecessary services. Less

attention is being given to a more **insidious** and **pervasive** requirement for doctors: attendance at meetings, the frequency of which is increasing so fast.

Meeting **mania**, a **rampant** phenomenon of the 1990s, occurs in all fields of work, wherever people in white collars or power suits **congregate**. "Sorry, he/she is in a meeting now," is the **ubiquitous** explanation used to explain unavailability. Why the **profusion** of meetings?

Text 2

Online-game **Mania**

The number of pupils having to wear glasses in our country continues to **burgeon** this year. Thus, educators often discuss the causes of this each time they **congregate**. Most of the focus is probably being directed toward **malpractice** in all aspects of the educational field. For example, they are **scrutinizing** the quality of textbooks. Less attention is being given to the **insidious** influence of online games. There are **profuse** pupils who often sit in front of computer screens continuously for long hours to play games. Some of them even have a **mania** for online games. With the **rampancy** of online games and the **ubiquity** of the Internet, the negative influence of online games on pupils' eyes becomes more **pervasive**.

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