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A CHINESE VOCABULARY LEARNING SYSTEM: LATENT SEMANTIC ANALYSIS APPROACH

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Abstract. *The present study aims on developing an LSA-based Chinese Vocabulary Learning System to learn Chinese words effectively and adaptively. Chinese words that were introduced in lessons were selected systematically by the statistical computation method of LSA (Latent Semantic Analysis). By the means of LSA, a list of prioritized vocabulary for different age groups will be provided by computing the relevancy between words in texts and Chinese children corpus. A total of 51 second graders (23 in the control group, 28 in the experimental group) underwent a 7-week intervention by two different vocabulary learning methods, traditional vocabulary learning and LSA-based vocabulary learning. Peabody Vocabulary, Chinese Character Recognition, and Word Association tests were administered before and after the intervention. The results of paired t-tests showed that the experimental group improved significantly after the 7-week intervention among tests, whereas none of the test improved significantly in the control group. Moreover, the results of ANCOVA indicate that after controlling for the effects of pretests, the experimental group performed significantly better than the control group on Chinese Character Recognition and Word Association. The results suggest that LSA-based vocabulary learning system is effective for vocabulary development among children who are learning to read Chinese.*
Keywords: Chinese, Latent semantic analysis, Vocabulary learning, Word association

1. Introduction.

Studies have shown that acquiring sufficient number of vocabulary is essential for reading and daily communication cross cultures and languages [1,2]. A vocabulary is learned when a child recognizes the word, obtains the definition of the word, identifies the logical relationship between the word and other words, and is aware of the function of the word when it appears in different contexts [1]. Therefore, successful vocabulary development requires systematic teaching and learning. Past studies have shown that, word definition, semantic mapping, and context clues are frequently-used instructional methods in Chinese lessons [3]. Regardless the method or strategy teachers traditionally used in the classroom settings, vocabulary that is taught in the classroom is chosen by teachers subjectively; in other words, teachers select the words to be introduced in the lessons based on their own experience and judgment. Without standardized criteria or systematic procedure, teachers face the dilemma of choosing the proper vocabulary that should be included or excluded in the reading lessons.

Computer-Assisted Vocabulary Learning (CAVL) has been widely used in language education. For example, Computer-Assisted Language Learning (CALL) systems, such as CAVOCA [4], WUFUN [5], and others [6,7] were applied in vocabulary learning. These programs were developed particularly for learning English as a foreign or second language.

However, so far, no Computer-Assisted Vocabulary Learning (CAVL) program has been developed for children who are learning to read Chinese. Conventionally, Chinese vocabulary learning relies largely upon dictionary search and classroom instructions, effective and convenient programs that provide systematic vocabulary learning is scarce.

In the light of the needs of language development, the present study aims to adopt a novel and effective approach for Chinese vocabulary learning, namely LSA-based Chinese Vocabulary Learning System. The system is here to provide teachers and students a more efficient and systematic tool for teaching and learning Chinese. The proposed approach, latent semantic analysis (LSA), measures the semantic relationship between words, sentences, and texts. The system includes two major modules, the core vocabulary recommendation and the automatic extended vocabulary recommendation. The core vocabulary recommendation was provided to assist teachers to select the main vocabulary terms that need to be learned for each unit, whereas the extended vocabulary recommendation was to help teachers and students to expand vocabulary terms efficiently and sufficiently.

2. **Vocabulary Learning and Instruction.**

The present study first reviewed the literature on vocabulary learning and instruction related to semantic network, the traditional Chinese vocabulary instruction, and CALL programs for vocabulary learning.

2.1. **Vocabulary learning.**

Two models are often applied in the vocabulary learning theory, the hierarchical network model and the spreading activation model [8]. In the hierarchical network model, vocabulary supplemented with semantic information is stored in the mental lexicon, similar to a semantic network. According to Collins and Quillian, the hierarchical network model consists of elements or nodes that stand below or above other elements in the network [9,11]. At every node, a word, supplemented with semantic information, is stored. The model used by Collins and Quillian is shown in Figure 1.

In contrast to the hierarchical network model, the network in the spreading activation model is similar to a web of interconnecting nodes [12]. The distance between the nodes are determined by the relations between the words, such as the degree of association between related concepts (words). The activation spreads from one node to the neighboring nodes and attenuates over distance, thus ensuring that closely related concepts are more likely to be activated than distant concepts. An example of the spreading activation model is shown in Figure 2. Each person has his/her own storage of mental lexicons and the one with larger amount of mental lexicons usually activates and retrieves the word faster during processing. Mental lexicons are restructured every time and a new vocabulary term is learned, at the same time; a new semantic network is reconstructed and enlarged

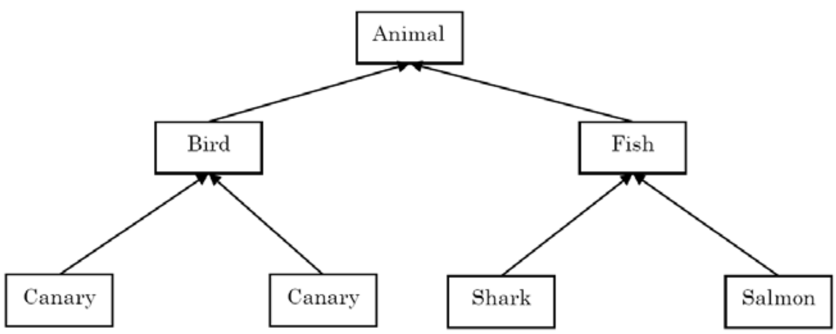

FIGURE 1. An example of the hierarchical network model (Collins and Quillian, 1969)

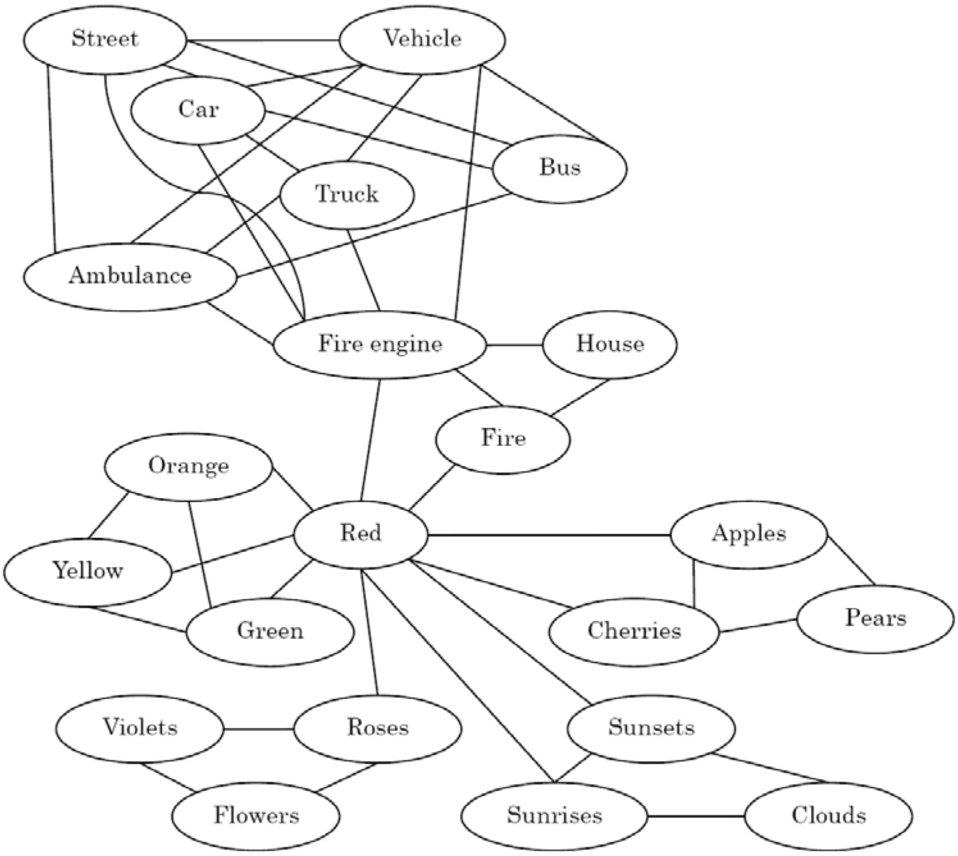

FIGURE 2. An example of the spreading activation model (Collins and Loftus, 1975)

[8]. The semantic space established by latent semantic analysis (LSA) is similar to the spreading activation model, in which the relations between words (vocabulary terms) are represented by cosine values. More details of latent semantic analysis (LSA) will be discussed.

2.2. **Vocabulary instruction.** Over the last few decades, strategies for vocabulary instruction, such as concept/wheels, webbing, semantic features analysis and semantic word mapping, were often used [13-15]. Particularly, semantic features analysis and semantic word mapping involve activities that are helpful in developing children's vocabulary skills [16]. Effective vocabulary activities help children to expand mental lexicons, to establish relationships between new words and existing concepts, and to acquire the meaning of new words [17].

In semantic features analysis, the teacher introduces the words, concepts, or features that are associated with other words in a grid. Students are asked to fill in the grid by deciding whether the concepts or features are positively or negatively related with each other. An earlier study has shown that semantic features analysis improved children's vocabulary skill and reading comprehension [17].

Semantic word mapping incorporates many of the recommended guidelines for vocabulary teaching, such as activating and building background knowledge, encouraging discussion about the attributes of words, and visually displaying the connections between the new word and existing concepts about the word [18,19]. Past studies have shown that semantic word mapping improved students' vocabulary skills. Zaid indicated that semantic mapping was not only an effective technique for teaching vocabulary but it also improved skills of note taking and creative thinking [20]. Recently, researchers used semantic word mapping for vocabulary teaching and found that semantic word mapping increased the scores of vocabulary tests among 7^{th} graders [21].

2.3. **Chinese vocabulary instruction.** Chinese language teachers usually develop a series of Chinese vocabulary learning materials for reading instruction, including word definition, semantic mapping, and context clues [3]. Activities of word definition involve searching the meaning and usage of words in dictionaries and introducing synonyms, antonyms and multiple-meaning of words. Semantic mapping, introduced by Johnson and Person in 1984 [18], teaches children skills of organizing vocabulary information and establishing connections between vocabulary and concepts. Context clues, on the other hand, unknown vocabularies are not directly taught but learned through analyzing and synthesizing the clues existed in the text [22-25]. The use of context clues improves reading comprehension, and help children to acquire various meanings of vocabulary terms. Previous studies have shown these instructional methods are effective, [26-28], however, vocabulary terms that were taught in reading lessons were chosen by teachers manually, no systematic and convenient tool was available to assist teachers to prepare reading lessons adequately and effortlessly. Therefore, developing a user-friendly vocabulary instructional system is crucial and beneficial for both instructors and learners.

2.4. **Computer-assisted vocabulary learning.** Computer-assisted language learning (CALL) provides language learners to learn language with multimedia content that increases motivation and the effectiveness of learning. Vocabulary learning has been a popular subject in CALL programs, and related programs have been developed, such as CAVOCA and WUFUN.

The program Computer-Assisted Vocabulary Acquisition (CAVOCA) was developed for vocabulary acquisition in foreign languages. It was designed by applying the theory of vocabulary acquisition to teach English words through a series of contextual examples [3]. WUFUN, on the other hand, was developed by Ma and Kelly in 2006 [5]; this program is computer-assisted vocabulary learning software that was designed to help Chinese university students to improve English vocabulary learning. Recently, a CALL program for learning Chinese as a foreign language was developed. Shei and Hsieh developed a Chinese CALL program for learning Chinese characters, words, and phrases for British students who were learning Chinese as a foreign language [6]. So far, no CALL program with the mechanism of automatic age-appropriate vocabulary terms selection was available for Chinese children.

To sum up, semantic networks, semantic features analysis and semantic word mapping and CALL programs are used in vocabulary learning in children reading lessons and foreign language learning, yet, no effective and efficient program is available for Chinese teachers and children. The present study developed an LSA-based Chinese vocabulary learning system with the mechanism of automatic age-appropriate vocabulary terms selection to help children to learn Chinese.

3. **Latent Semantic Analysis.**

Latent Semantic Analysis (LSA) is a technique for extracting and representing the semantic meaning of words based on a large corpus of text [29]. LSA uses the corpus to represent a word-document co-occurrence matrix, and the matrix is decomposed into vector space of word-document vector using singular value decomposition (SVD). Then, dimension reduction is used to remove the extraneous information and variability of the vector space. After dimension reduction, the semantic space is established.

LSA produces the similarity measure of two words (or sentences) based on the semantic space. In the semantic space, each word or text unit is represented as a vector. LSA computes their similarity by computing the cosines of their vectors. The more similar the vectors are, the higher the LSA cosine is. Previous studies showed that LSA-based assessments are as reliable as human raters who have been asked to make the same judgments [29,30].

3.1. **Applications of LSA in education.** In previous studies, few systems were developed by applying LSA in education, for example, AutoTutor, Summary Street, and iSTART. These systems were developed based on the LSA similarity measures.

AutoTutor is a computer tutor based on the construct theories of learning and simulates a human by holding conversations with students in the natural language. AutoTutor has been developed and applied in Newtonian physics and computer literacy [31,32]. The program typically takes 50-200 conversational turns between the tutor and student to answer the main question, including pumps, hints, and prompts.

Summary Street is a web-based educational system based on LSA that was developed to help students improve their summarization skills. Summary Street supports reading and writing activities through which students develop and expand their knowledge in new topic areas [33,34]. The system provides feedback on written summaries by using LSA, and LSA is used to match the student summary with the text generated by experts' summaries [35].

iSTART is a web-based system that teaches students to use reading strategies to improve their ability to explain concepts to learners themselves. LSA is applied to this system to provide appropriate feedback for learners. The system uses LSA to measure the similarity of a learner's explanation to each of the benchmarks for every sentence in the texts [36]. Indeed, Mcnamara, Boonthum, Levinstein and Millis verified that iSTART systems that incorporate LSA classified self-explanations more accurately than did the word-based systems [37].

However, LSA studies in Chinese education are still scarce. The applications of LSA in vocabulary learning have massive practical and theoretical values for Chinese education. Therefore, in the present study, LSA-based Chinese Vocabulary Learning System was developed and applied with two major modules: the core vocabulary recommendation and the automatic extended vocabulary recommendation.

4. **LSA-based Chinese Vocabulary Learning System.** In this study, the LSA-based Chinese Vocabulary Learning System incorporated LSA to automatically and systematically provide proper vocabulary recommendation that could help teachers select vocabulary and teach the students more vocabulary terms. The proposed system was developed by using the semantic relationship between the vocabulary terms that are already presented in the Chinese children's semantic space. The system provides adaptive core vocabulary and extended vocabulary recommendation lists, and each vocabulary is accompanied with its definition and an example sentence.

4.1. **Core vocabulary recommendation.** For vocabulary learning, how to define and select the core vocabulary that is related to the Chinese unit being taught is important. However, traditionally, core vocabulary selected manually by teachers is largely influenced by teacher's experience and background. Moreover, the most widely used criteria for teachers to define the importance of vocabulary terms is word frequency, yet, reading instructions that emphasize on frequent words will impede the expansion and development of mental lexicon. A study examined the role of each vocabulary term in a sentence and found that the vocabulary term with the largest vector had the biggest contribution to

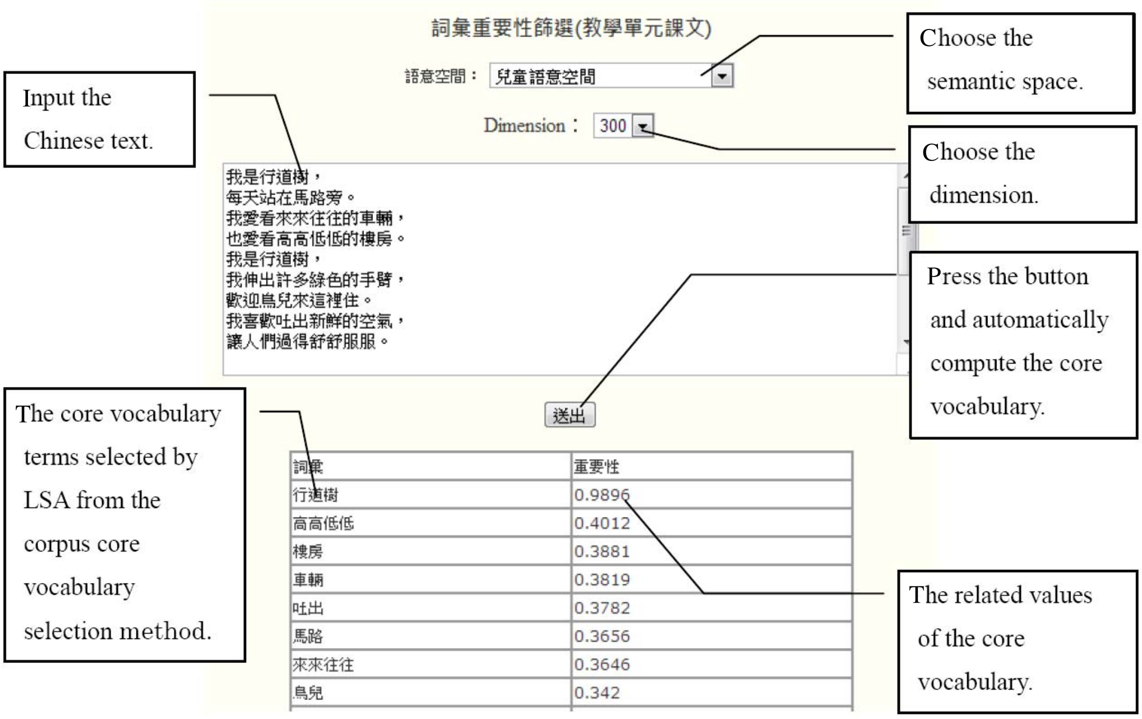

FIGURE 3. The interface of core vocabulary recommendation

the text. The overall correlation of the LSA values to the vector lengths was $-.94$ [38] suggests that word selection should put vector lengths into consideration; word frequency should not be used as the single criterion. Based on the previous findings, the proposed module utilized the systematic core vocabulary recommendation method, in which the vector length of the vocabulary term in the semantic space and the vocabulary frequency in the corpus were considered. The core vocabulary recommendation method is shown in Equation (1):

$$\log\left(\frac{\|T_i\|}{tf_i}\right), \quad i = 1, 2, \ldots, n \tag{1}$$

where $\|T_i\|$ is the vector length of vocabulary i in the semantic space, and tf_i is the total frequency of vocabulary i in the corpus. The module interface is shown in Figure 3. Teachers can input the Chinese text; then, the module will compute the vocabulary terms related to the text using Equation (1). Teachers can select the core vocabulary terms in the Chinese text by considering the outcome of the core vocabulary recommendation.

In each Chinese unit, teachers picked six core vocabulary terms that were most related to the unit, and children were required to learn these core vocabulary terms. The learning interface of the core vocabulary terms is shown in Figure 4.

4.2. **Extended vocabulary recommendation.** It is important for children to learn more related vocabulary terms in each unit. However, it is difficult to select the extended vocabulary terms systematically and automatically. The proposed extended vocabulary recommendation was developed to select the extended vocabulary terms that are related to the core vocabulary based on the word's semantic similarity. The present study established a Chinese children's semantic space based on Chinese children corpus generated from children textbooks and computed the semantic relations automatically between the core vocabulary terms and other vocabulary terms in the semantic space. For any vocabulary term, the semantic relation is computed as the cosine of the vector representations,

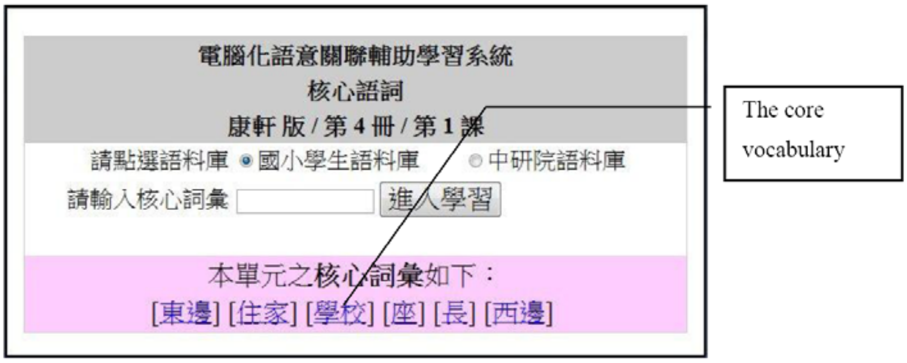

FIGURE 4. The interface of core vocabulary recommendation

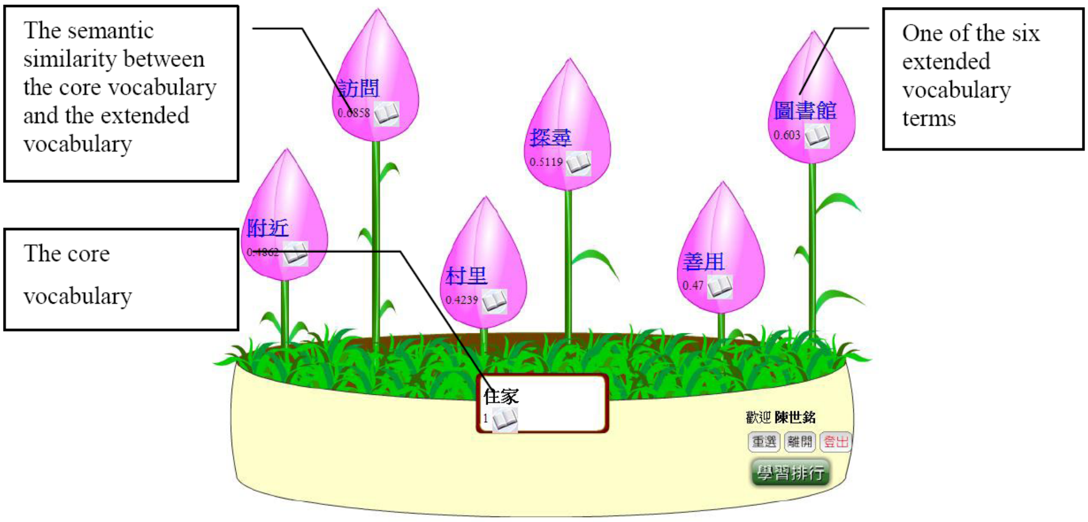

FIGURE 5. The interface of automated extended vocabulary recommendation

following Equation (2).

$$\cos(t_i, t_j) = \frac{t_i t_j^T}{\|t_i\| \, \|t_j\|} \tag{2}$$

Six vocabulary terms that were most associated with each core vocabulary terms were selected as the extended vocabulary terms, therefore, each core vocabulary term comes with six extended vocabulary terms (see Figure 5).

4.3. **The vocabulary explanation with an example sentence.** Each vocabulary term has its own explanation and an example sentence that helps the students to obtain the meaning and usage of the term. Once the word is tapped, the tulip blossoms and indicates that the word has been learned. The flowers that remain in buds indicate that they have not been learned yet (see Figure 6). For example, the blossomed flower 教育 (education) indicates that it has been tapped and learned.

5. **Method.** A total of 51 second graders (G2) at an elementary school in Taichung, Taiwan participated in this study, including 28 students in the experimental group and 23 students in the control group. None of the children were previously diagnosed with any emotional, behavioral or sensory difficulties. To develop the Chinese semantic space, the study used the Chinese children corpus established by Liao [39]. The Chinese children corpus originally contains 945 documents and 16,091 words (terms) that are used in the

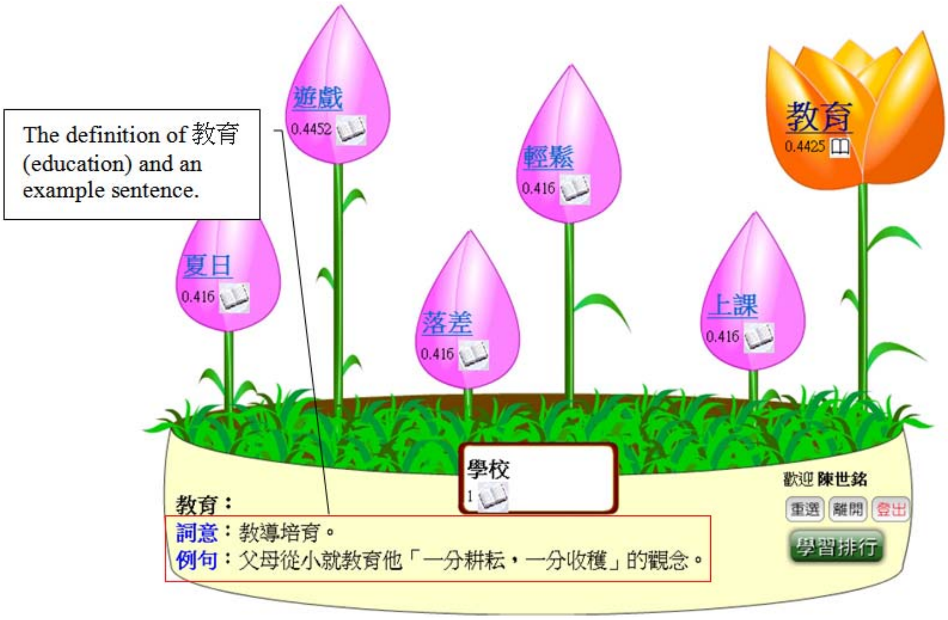

FIGURE 6. The vocabulary explanation interface, with an example sentence

TABLE 1. Research design

Group	Learning method	Control variables	Dependent variables (post-tests)
Control group	Traditional Learning	1. Baseline behavior (pre-tests) 2. Teaching time 3. Teaching materials	1. Peabody Vocabulary test 2. Chinese Character Recognition test 3. Word association test
Experimental group	LSA-based Chinese Vocabulary Learning		

elementary schools in Taiwan. Among 945 documents, only the narratives were used in the present study to establish a Chinese semantic space and ended up with 355 documents and 3,989 words (terms).

The present study examined the effectiveness of the system by comparing the learning outcomes of controlled group and experimental groups. The controlled group was taught by traditional vocabulary learning method and the experimental group was taught by LSA-based vocabulary learning method proposed in the study. The research design is presented in Table 1. Three variables were controlled before the experiment was conducted: baseline behavior, teaching time, and teaching materials. Peabody Vocabulary test, Chinese Character Recognition test, and word association test were assessed before and after the intervention as the baseline behavior and dependent variables (post-tests).

Peabody Vocabulary test is a standardized test that measures linguistic intelligence. This test has 125 items, and the reliability ranges from .90 to .97. Chinese Character Recognition test evaluates the number of vocabulary terms that are learned by students in grade 1 and grade 2. The test has 31 items, and the reliability is above .80. Word association test was developed in the present study to evaluate student's word association skills. Two scores, the number of word association and the category of word association, were obtained from word association test and will be further discussed.

The independent samples t-test was used to confirm that there was no significant difference in the baseline behavior between the control group and experimental group. The paired-samples t-test was used to compare the performance of the two vocabulary learning methods between the pre-tests and post-tests. An analysis of covariance (ANCOVA) by controlling the effects of pre-tests was further used to compare the performance of vocabulary learning among the two groups.

6. **Results.** The results of independent t-test showed that there were no significant differences (p-value>0.05) in the pre-tests (baseline behavior) between the control group and the experimental group. A paired samples t-test was used to examine the performance of the interventions among the two groups. The results of paired samples t-tests showed that the control group had no significant difference between the pre-test and post-test, even though the means of post-tests were higher than the pre-tests, with the exception of the categories of word association (Table 2); on the other hand, the results showed that the experimental group performed significantly better on all the tests after the intervention (Table 3). The results suggest that LSA-based Chinese Vocabulary Learning system is helpful in children's vocabulary development.

To compare the performance of the two instructional methods ANCOVA was applied. The pre-tests were used as the covariate in ANCOVAs. The Johnson-Neyman analysis was used to examine the difference between the control group and the experimental group for Peabody vocabulary post-test because the analysis of homogeneity of the regression coefficient was significantly different. The results of the Johnson-Neyman analysis showed that there was a significant difference between the control group and the experimental group when the students' test score was below 121, and the experimental group did better than the control group. In addition, there was no significant difference between the two groups for test score of 121-145 (the highest test score).

Table 4 showed the adjusted mean and standard deviation of the post-tests score in the control group and the experimental group. Overall, the students' performances in the experimental group were better than the control group on the post-tests. The results of ANCOVA for Chinese character recognition post-test scores were shown in Table 5, and there was significant difference between the two groups.

The result of the ANCOVA showed that the scores of number of word association were significant, and the experimental group was significantly better than the control group

Table 2. Paired-samples t-test results in the control group

Test	Pre-test mean score	Post-test mean score	t-value
Peabody Vocabulary test	122.65	123.09	–.222
Chinese Character Recognition	1292	1296.30	–.098
number of word association	65.65	69.78	–1.300
category of word association	25.22	23.48	1.525

Table 3. Paired-samples t-test results in the experimental group

Test	Pre-test mean score	Post-test mean score	t-value
Peabody Vocabulary test	120.25	127.14	–2.416*
Chinese Character Recognition	1335.61	1522.46	–4.865***
number of word association	56.21	80.07	–9.473***
category of word association	23.93	30.54	–5.195***

*p<0.05; **p<0.01; ***p<0.001

Table 4. The adjusted mean and standard deviation of the variables for the two groups

Variable	Experimental group		Control group	
	M	SD	M	SD
Chinese Character Recognition test	1509.455	35.390	1312.141	39.060
number of word association	84.274	2.744	64.667	3.035
category of word association	30.974	1.144	22.945	1.263

Table 5. Chinese character recognition post-test (ANCOVA)

Source	Type III Sum of Squares	df	MS	F
Pre-test	1602900.867	1	1602900.867	45.843***
Groups	488420.374	1	488420.374	13.969***
Error	1678336.967	48	34965.353	

*p<0.05; **p<0.01; ***p<0.001

Table 6. Number of word association post-test (ANCOVA)

Source	Type III Sum of Squares	df	MS	F
Pre-test	22495.455	1	22495.455	109.043***
Groups	4628.753	1	4628.753	22.437***
Error	9902.315	48	206.298	

*p<0.05; **p<0.01; ***p<0.001

Table 7. Category of word association post-test (ANCOVA)

Source	Type III Sum of Squares	df	MS	F
Pre-test	1202.672	1	1202.672	32.949***
Groups	805.897	1	805.897	22.079***
Error	1752.032	48	36.501	

*p<0.05; **p<0.01; ***p<0.001

(Table 6). Similarly, there was significant difference in the category of word association between the two groups (Table 7). In summary, the results of ANCOVAs indicated that children learn vocabulary more effectively and sufficiently by using LSA-based Chinese Vocabulary Learning system than the traditional vocabulary learning. Students improved significantly on the number of vocabulary terms learned and the ability of word association by the proposed system.

7. **Discussion and Conclusion.** In traditional vocabulary instruction methods, there is no objective criterion and systematic method to help teachers to select proper vocabulary for students. The present study aims to develop a system with LSA to provide teachers and students a convenient and efficient tool for reading lessons. The major contributions of the present study are:

i) propose a novel vocabulary recommendation method
ii) develop a computerized vocabulary learning system
iii) examine the effectiveness of the proposed method and system

The study examined the effectiveness of the computer vocabulary learning system by comparing it with the traditional Chinese vocabulary learning method.

The results of the paired-samples t-tests for Peabody Vocabulary test and Chinese Character Recognition test showed that the students who were taught by the LSA-based Chinese Vocabulary Learning System achieved higher scores, moreover, the performance of related tests improved significantly after the intervention. It is important for children to learn the core vocabulary terms that are required in the instructions. These required terms enable children to comprehend what is being taught in school, at least at the basic and preliminary level. In the present study, the system provided the core vocabulary terms that are essential for each unit, and provided extended vocabulary terms that are closely related to the core vocabulary. As discussed earlier, the system applied the theory similar to the spreading activation model. In this model, the network is like a web of interconnecting nodes [12]. The activation spreads from one node to the neighboring nodes, and the closed neighbors are activated faster than the further neighbors due to distance, therefore, the closely related concepts are more likely to be activated than distant concepts. LSA-based Chinese Vocabulary Learning System was designed on the ground of the spreading activation model that enables children to acquire, to store, to activate, and to expand mental lexicon efficiently. The extended vocabulary terms were selected by considering the semantic similarity between the core vocabulary and extended vocabulary terms, therefore, instead of tying the nodes randomly, the system offers a list of pre-organized vocabulary that is semantic related, which allows children to learn more words in a short period of time. The experimental group performed significantly better on the test of word association and showed significant improvement after the intervention indicated that LSA-based learning system help children to build the network of mental lexicon sufficiently. Moreover, offering vocabulary explanations and example sentences also help children to acquire the correct meaning of the word and to use the word appropriately.

The present study also compared the performance of vocabulary learning for students using LSA-based Chinese Vocabulary Learning system and the traditional learning method. A significant improvement was observed in children's vocabulary learning performance (assessed by Chinese Character Recognition test, number of word association test, and category of word association test) by using the proposed system. For Peabody Vocabulary test, only children who scored below 121 were significantly different between the two methods, no significant difference was observed for children who scored 121 to 145. It suggests that children with better vocabulary knowledge show limited improvement with the intervention due to the sufficient number of vocabulary they have already learned, on the other hand, children with less vocabulary knowledge will benefit from the systematic way of vocabulary learning.

In sum, the present study provides empirical evidence that LSA-based systematic vocabulary learning system helps children to learn vocabulary better than the traditional method. The proposed CAVL program significantly improved children vocabulary development by increasing the number of vocabulary and promoting awareness of word association. The system will become an efficient and convenient tool for teaching and learning Chinese.

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