Chen, C.-M., & Hsu, S.-H. (2008). Personalized Intelligent Mobile Learning System for Supporting Effective English Learning. *Educational Technology & Society*, *11* (3), 153-180.

Personalized Intelligent Mobile Learning System for Supporting Effective English Learning

Chih-Ming Chen
Graduate Institute of Library, Information and Archival Studies, National Chengchi University, Taiwan // chencm@nccu.edu.tw

Shih-Hsun Hsu
Graduate Institute of Network Learning Technology, National Central University, Taiwan // jason@cl.ncu.edu.tw

ABSTRACT

Since English has been an international language, how to enhance English levels of people by useful computer assisted learning forms or tools is a critical issue in non-English speaking countries because it definitely affects the overall competition ability of a country. With the rapid growth of wireless and mobile technologies, the mobile learning has been gradually considered as a novel and effective learning form because it inherits all the advantages of e-learning as well as breaks the limitations of learning time and space occurring in the traditional classroom learning. To provide an effective and flexible learning environment for English learning, this study adopts the advantages of the mobile learning to present a personalized intelligent mobile learning system (PIMS) which can appropriately recommend English news articles to learners based on the learners' reading abilities evaluated by the proposed fuzzy Item Response Theory (FIRT). In addition, to promote the reading abilities of English news, the unknown or unfamiliar vocabularies of individual learner can also be automatically discovered and retrieved from the reading English news articles by the PIMS system according to the English vocabulary ability of individual learner for enhancing vocabulary learning. Currently, the PIMS system has been successfully implemented on the personal digital assistant (PDA) to provide personalized mobile learning for promoting the reading ability of English news. Experimental results indicated that the proposed system provides an efficient and effective mobile learning mechanism by adaptively recommending English news articles as well as enhancing unknown or unfamiliar vocabularies' learning for individual learners.

Keywords

Mobile learning, Personalization, Intelligent tutoring system, English Learning

Introduction

Traditional teaching resources, such as textbooks, typically guide the learners to follow fixed sequence to other subject-related sections related to the current one during learning processes. Web-based instruction researchers have given considerable attention to flexible curriculum sequencing control to provide adaptable, personalized learning programs; therefore, many powerful personalized/adaptive guidance mechanisms, such as adaptive presentation, adaptive navigation support, curriculum sequencing, and intelligent analysis of learner's solutions, were proposed to aid more efficient learning (Lee, 2001; Tang & Mccalla, 2003; Papanikolaou & Grigoriadou, 2002). Currently, most adaptive/personalized tutoring systems consider learner/user preferences, interests, and browsing behavior when investigating learner behavior for personalized services. However, these systems neglect the importance of learner ability when implementing personalized mechanisms. On the other hand, some researchers emphasized that personalization should consider levels of learner knowledge, especially in relation to learning (Chen *et al.*, 2005; Chen *et al.*, 2006; Brusilovsky, 1999). That is, considering learner ability based on major fields and subjects can promote personalized learning performance.

In recent years, the fastest growing web community is mobile visitors who browse web pages or retrieval web information using PDAs or cell phones by wireless networks. Similarly, the development of educational technologies also tends to be more mobilized, portable, and personalized. These trends lead to the learning form is dramatically changing from the traditional classroom learning to the electronic learning (E-learning) (Lin & Hsieh, 2001), mobile learning (M-learning) (Chang *et al.*, 2003; Cabrera *et al.*, 2005; Ting, 2005; Holzinger *et al.*, 2005) or even ubiquitous learning (U-learning) (Wang, 2004; Rogers *et al.*, 2005; Tummala & Jones, 2005; Wilkerson *et al.*, 2005) due to fast development of communication technology. Among these novel learning forms, mobile learning

has been considered as an effective form of flexible learning because it is possible to break the limitation of teaching place where must take place in a classroom or located computers. In the meanwhile, mobile learning is also helpful to perform learning activities utilizing learner's spare time at any time from any place with wireless networks.

Since English has been the most important second language (L2) in many non-English speaking countries, developing useful computer assisted learning forms or tools for supporting effective English learning is a critical issue in the English-language education field (Collins, 2005; Shih, 2005). Learning English involves memorization and practice of a large number of vocabulary words and grammatical structures. Recently, some scenarios of mobile learning have been successfully proposed to aid language learning activities of outside classroom, such as TenseITS, a mobile intelligent tutoring system with learner's location awareness for supporting language learning, designed primarily for Chinese learners of English (Cui & Bull, 2005), cell phone assisted language learning system (Kiernan & Aizawa, 2004; Chinnery, 2006), and so on. Any language learning can be divided into four issues including listening, reading, speaking, and writing skills; however, Huckin *et al.* (1993) indicated that reading ability and vocabulary knowledge are two of the most important components of performance in a second language and depend on the other, especially in academic settings. In other words, reading can help language learners to acquire vocabulary and vocabulary knowledge is helpful to promote reading comprehension. Alderson (1984) proposed that the interpretation of words and syntactic structures - that is, grammar and vocabulary – is the main factor in poorer reading performance in the second language than in the first language (L1). Nation (1993) also proposed that the growth of reading skills is beneficial to develop knowledge of the world, and simultaneously increase basic academic and technical vocabularies. Moreover, Coady's study (1997) pointed out that extensive reading is an effective way to promote learners' reading performance. Generally, the extensive reading method frequently recommended by English teaching experts is to read storybooks, magazines, periodicals and newspapers printed in English. Hwang and Nation's study (1989) emphasized that newspapers constantly repeat some frequent words and technological terms related to a topic. Multiple repeated vocabularies can reduce readers' lexical loading and activate their imagination, experience, and background knowledge to better extract information from the reading text. Additionally, newspapers provide benefits to learn practical vocabularies frequently used in daily lives. However, readers often suffer many difficulties while reading English newspapers due to too many unfamiliar or unknown words used in various professional domains.

In addition, Jolly (1978) claimed that success in reading a foreign language mainly depends on one's first-language reading ability rather than on the learners' level of first-language. Namely, the foreign language reading is a reading problem, not a language problem. Coady (1973) thought that the reading process is much the same for all language. That is, good native language readers can be logically expected to be good second language readers. Yorio (1971) proposed that the reading problems of foreign language learners are due largely to imperfect knowledge of the language, and to native language interference in the reading process. However, some researches (Kern, 1994; Upton & Lee-Thompson, 2001) took a contrary view on the topic of "first language interference" to indicate that L2 readers often access to their L1 and use this resource as a strategy to help them comprehend an L2 text. Moreover, many empirical evidences (Alderson, 1984) showed that poor foreign language reading is due to incorrect strategies for reading that foreign language, strategies which differ from the strategies for reading the native language. Restated, poor foreign language reading is due to reading strategies in the first language not being employed in the foreign language. Furthermore, some researches (Carrell, 1991; Lee & Schallert, 1997) clearly mentioned that L2 proficiency influences overall L2 reading ability.

To conquer the problems of English learning, specially for reading and vocabulary acquisition, the common advice from many English teachers on the best way for learning English is "little and often" (Buda, 1984). Restated, a few minutes every day is certainly much better than a few hours once a month. Therefore, this study adopts the advantages of the mobile learning in terms of easily breaking the limitations of time and space and utilizing spare time for ubiquitous learning. Meanwhile, developing a personalized reading learning strategy to enhance reading learning of individual learners was also a concerned issue in the study. To integrate the mobile learning with the proposed personalized reading learning strategy, this study presents a personalized intelligent mobile learning system (PIMS) based on the proposed fuzzy Item Response Theory, which can conduct personalized curriculum sequencing, for supporting effective English reading learning for individual learners. Here, the electronic English news articles automatically retrieved from English news sites (FTV http://englishnews.ftv.com.tw/index.asp) by an intelligent crawler agent are used as the course materials for personalized mobile learning in the proposed PIMS system. Meanwhile, the unknown or unfamiliar vocabularies of individual learner can also be automatically discovered and retrieved from the reading English news articles by the PIMS system according to the English vocabulary ability of

individual learner for promoting reading learning by enhancing vocabulary learning. Experimental results indicated that the proposed PIMS system provides benefits to promote learner's reading ability of English news articles, vocabulary ability, and learning interests due to providing personalized and flexible mobile learning mechanisms for individual learners.

System Design

This section describes the details of the proposed system architecture. An overview of system architecture is presented in the first subsection. The other subsections describe the English e-news archive procedures, detail the scheme of measuring difficulty of English news, explain the schemes of the personalized English news recommendation and personalized vocabulary recommendation.

System Architecture

A personalized intelligent mobile learning system (PIMS) supported by the personalized vocabulary learning system (Chen & Chung, 2006), which includes a remote courseware server, client mobile learning system, and data synchronized agent, is presented herein. Figure 1 shows the detailed system architecture. The client mobile learning system which consists of four intelligent agents and four databases can appropriately recommend English news articles for individual learners to enhance their reading abilities as well as vocabulary abilities for individual learners based on the proposed fuzzy Item Response Theory (FIRT). The remote courseware server containing three intelligent agents and one database aims at automatically collecting English news articles from the Internet by an intelligent crawler for the remote courseware & user portfolio database and evaluating the difficulty parameters of English news articles by the proposed scheme of measuring difficulty of English news articles. Moreover, to support the off-line learning mode, the data synchronized agent is in charge of keeping data consistency between the client databases with the server databases after the wireless network recovers on-line connection. In this work, the merge replication technique provided in Microsoft SQL server was employed to perform this work. The detailed system components are explained in the following subsections.

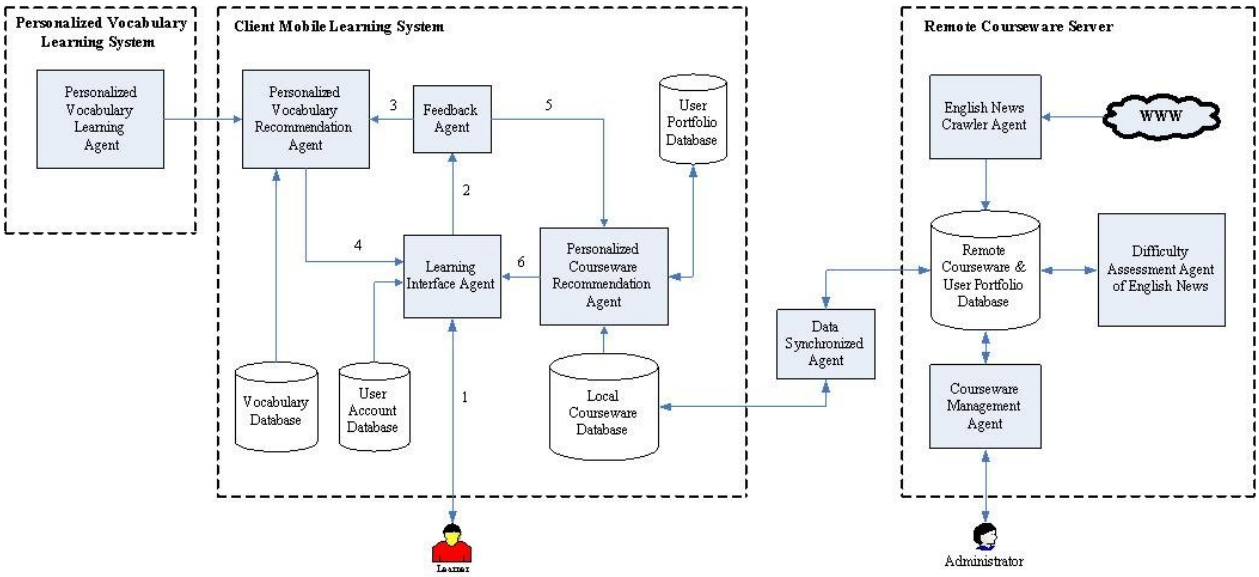

Figure 1. The system architecture of the proposed PIMS system

The Remote Courseware Server

In Fig. 1, the right part reveals the system architecture of the remote courseware server, which includes the English news crawler agent, difficulty assessment agent of English news, courseware management agent, and remote

courseware & user portfolio database. Currently, many web sites have provided a large amount of free English news articles with corresponding Chinese translations for readers' browsing in Taiwan, such as FTV and CTV English news sites (http://www.cts.com.tw/news/insidetaiwan/). These corresponding Chinese translations are helpful to speed up the comprehension degree of reading for Chinese readers while reading an English news article. To construct abundant English news courseware for the reading learning services of English news articles, the needed course materials are automatically retrieved and stored into the remote courseware & user portfolio database from the Internet by the English news crawler agent. The English news crawler agent aims at automatically gathering English news articles and extracting metadata contained in news articles from English e-news site to conduct the job of English E-news archive. Moreover, the difficulty assessment agent of English news is in charge of automatically measuring the difficulty parameters of English news articles according to vocabulary grading levels of General English Proficiency Test (http://www.gept.org.tw/indexie.asp) in Taiwan and the proposed reading ease formula modified from Flesch reading ease formula (Flesch, 1948). These measured difficulty parameters will be utilized to recommend appropriate English news articles to individual learners based on the proposed fuzzy Item Response Theory. Finally, the courseware management agent with authorized account management mechanism provides a friendly courseware management interface to aid teachers to create new course units, upload courseware to the remote courseware & user portfolio database and delete or modify courseware from the remote courseware & user portfolio database.

The Client Mobile Learning System

The central part shown as Fig. 1 displays the system architecture of the client mobile learning system which includes four intelligent agents and four databases. The learning interface agent aims at providing a flexible learning interface for the legal learners with registered accounts stored in the user account database to interact with the feedback agent, personalized courseware recommendation agent, and personalized vocabulary recommendation agent. It provides a friendly learning interface to show the English news articles recommended from the personalized courseware recommendation agent, a user interface for collecting learner's learning responses, an English vocabulary learning interface for learning new vocabularies, and a checking vocabulary interface for confirming acquired English vocabularies. The feedback agent aims at collecting learner explicit feedback information that includes the difficulty levels and comprehension degrees of the learned English news articles from the learning interface agent and storing them in the user portfolio database for personalized English news article recommendation. The personalized courseware recommendation agent is in charge of recommending personalized courseware from the local courseware database to individual learner, then evaluates learner reading ability according to learner feedback responses based on the proposed fuzzy Item Response Theory. Finally, to promote the reading ability of English news article by enhancing learner vocabulary ability, the personalized vocabulary recommendation agent extracts the new vocabularies to individual learners from the learned English news articles based on the vocabulary abilities of individual learners measured by the personalized vocabulary learning system (Chen & Chung, 2006) and the difficulty parameters of vocabularies. The personalized vocabulary learning system was presented to promote the learning performances and interests of learners' English vocabulary learning based on Item Response Theory and learning memory cycle, which can recommend appropriate English vocabularies for learning according to individual learner vocabulary ability and memory cycle. It was successfully implemented on personal digital assistant (PDA) for personalized English vocabulary learning without constraints of time or place by mobile devices.

Basically, if the difficulty parameters of the appeared vocabularies in the learned English news article are larger than the current learner vocabulary ability, then these corresponding English vocabularies will be served as likely new vocabularies to show for the learner. Furthermore, a checking vocabulary interface is used to confirm whether these new vocabularies have been acquired by the learner after the learner finishes the vocabulary learning. In the meanwhile, these acquired vocabularies will be simultaneously recorded in the client and server user portfolio databases through the data synchronized agent to avoid repeated vocabulary learning in the next learning cycle. Currently, the vocabulary database contains over eight thousands vocabularies with corresponding Chinese translations and difficulty parameters collected from the vocabulary repository of General English Proficiency Test in Taiwan. The aim of the GEPT test is to provide a fair and reliable check for each level of ability in English. Currently, the GEPT is divided into five levels with content as appropriate to each level, and each level incorporates listening, reading, writing and speaking components. The elementary, intermediate, and high-intermediate levels are administered twice a year, the advanced level once a year, and the superior level upon request. The following section details the system architecture operating procedure.

The Learning Procedure of the Client Mobile Learning System

Based on the system architecture, the details of system operation procedure of the client mobile learning system are illustrated as Fig. 2, and described as follows:

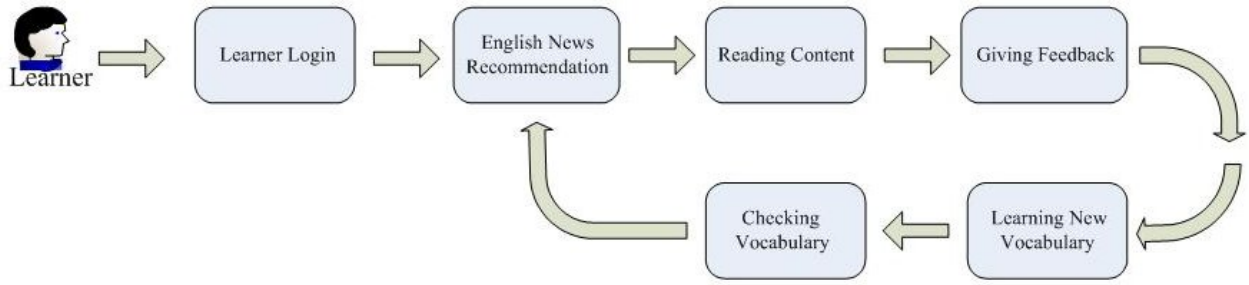

Figure 2. The learning procedure of the client mobile learning system

Step 1. Learner logs in the client mobile learning system through the learning interface agent. As a learner logs in the system, the learning interface agent will check his account in the user account database. If the learner has already registered and owned past learning records, the system will get his reading ability from the user portfolio database; otherwise, the learner is viewed as a beginner.

Step 2. The personalized courseware recommendation agent gets the contents of English news courseware from the local client courseware database, and then the learning interface agent exhibits the learning contents received from the personalized courseware recommendation agent for the beginner. If the learner has been an experienced learner in our system, the learning interface agent will get his past learning records from the user portfolio database to provide personalized learning services through recommending appropriate English news articles to the learner.

Step 3. As the learner clicks a piece of English news title, the learning interface agent will get the content of the clicked English news article with corresponding Chinese translations from the local client courseware database and exhibits it to the learner. To read the content of English news article conveniently, each piece of English news was segmented into many small paragraphs with corresponding Chinese translations for learners. The PIMS system provides two switch learning modes, i.e. English mode and Chinese mode, to learners for English news reading learning.

Step 4. The learner needs to reply to two simple questionnaires, i.e. the difficulty levels with three various grading scales (easy, moderate or hard) and the comprehension degree (from zero percent to one hundred percent) for the learned English news article in order to obtain personalized learning services in the next learning cycle. These feedback responses are collected by the feedback agent and stored in the user portfolio database for personalized English news article recommendation.

Step 5. The personalized vocabulary recommendation agent extracts the unfamiliar or new vocabularies with corresponding Chinese translations to individual learners according to the learners' vocabulary abilities measured by the personalized vocabulary learning system (Chen & Chung, 2006).

Step 6. The personalized vocabulary recommendation agent will summarize all learned vocabularies using the vocabulary checking interface after the learner finishes the unfamiliar or new vocabularies' learning. The aim is to perform the confirming process for the acquired vocabularies, then the proposed system will store these acquired vocabularies into the user portfolio database.

Step 7. Finally, the personalized courseware recommendation agent will re-evaluate the learner new reading ability according to the explicit feedback responses of two simple questionnaires, then return **Step 2** for the next learning cycle.

English E-News Archive

The English E-news archive aims at automatically gathering English news articles and extracting metadata contained in news articles from FTV English e-news site utilizing an intelligent crawler agent with metadata extraction mechanism. These retrieval English news metadata including English and Chinese news titles, URL address, date,

and news body was stored in the remote courseware & user portfolio database. Finally, the metadata extraction process automatically extracts the meaningful metadata by the matching technique of regular expression and stores them in the remote courseware & user portfolio database.

Measuring Difficulty of English News Article

Generally, the difficulty of English article can be viewed as readability and the past proposed evaluation schemes relating to readability are over thirty (Flesch, 1948; Klare, 2000). Among the proposed schemes, Flesch's reading ease formula (Flesch, 1948) presented in 1948 is the most widely used approach to evaluate the difficulty for a piece of English article. Currently, Flesch's reading ease formula is also employed to evaluate the difficulty of English article in the Microsoft Office Word. However, Flesch's reading ease formula does not consider the differences of native with non-native English speakers while evaluating the difficulty of English article. That is, the reading difficulties are different for native and non-native English speakers while reading the same piece of English article. Therefore, to evaluate difficulty of English article for non-native speakers more precisely, this study integrates Flesch's reading ease formula with the proposed difficulty parameter inferred by a fuzzy rule base based on the percentage of vocabulary occurring in various GEPT grading levels to present a novel readability measure for estimating difficulty of English news article. Next, the details of the proposed evaluation scheme are explained in the following subsections.

Measuring the Difficulty of English news by Flesch Reading Ease Formula

Flesch's reading ease formula employed the average sentence length in a piece of English article and the average number of syllables per word to measure the difficulty of English article. Flesch's reading ease formula can be formulated as follows:

$$\mathrm{RE} = 206.835 - (1.015 \times \mathrm{ASL}) - (84.6 \times \mathrm{ASW}) \quad (1)$$

where the RE represents the reading ease value, i.e. difficulty, and the range of RE is between 0 to 100, ASL is the average sentence length in a piece of English article which can be measured using the total number of vocabularies divided by the total number of sentences, ASW is the average number of syllables per word which can be measured using the number of syllables divided by the number of vocabularies in a piece of English article.

In Eq. (1), if the measured RE value is equal to zero, then the English article is viewed as the most difficult for reading. This situation occurs under the measured ASL and ASW values are over 37 and 2, respectively. Flesch's study (1948) indicated that the English article is the most appropriate for reading if the measured RE value is equal to 65. Besides, to integrate Flesch's reading ease value with the difficulty parameter of English article inferred by a fuzzy rule base using a linear combination with an adjustable weight, the range of the RE value must be normalized as the same range with the inferred difficulty (i.e. -3 to +3). The integrated difficulty of English news article will be applied to serve as the key parameter to recommend appropriate English news article for individual learners using the proposed fuzzy Item Response Theory. The normalized formula of the RE value can be formulated as follows:

$$\mathrm{RE}' = \mathrm{RE} \times (\frac{-6}{100}) + 3 \quad (2)$$

where the RE' represents the normalized RE value.

The Proposed Scheme for Evaluating Difficulty of English News Article

We can logically infer that most part of learners can easily read the contents of some news article if most part of vocabularies used in this news article belong to the elementary level, even the English news has high ASL and ASW values measured by Flesch's reading ease formula. That is, the difficulty parameter of this English news article should be descended in this situation. However, Flesch's reading ease formula neglects to consider the difficulties of vocabularies used in an English article while measuring the difficulty of English article. Based on the problem, this section presents a novel scheme to infer the difficulty of English article by a pre-designed fuzzy rule base based on the percentage of vocabulary occurring in various GEPT grading levels.

(1) Computing the Percentages of Vocabulary that Appear in Various GEPT Grading Levels for All Gathered English News

At present, the proposed PIMS system contains about 2792 pieces of English news articles, two thousands one hundred vocabularies of elementary level, two thousands six hundreds vocabularies of intermediate level, and three thousands two hundreds vocabularies of high-intermediate level. To infer the difficulty of an English news article, the proposed PIMS system will compute respectively the percentages of vocabulary occupying in three grading levels for all gathered English news articles.

(2) Determining Fuzzy Membership Functions by the K-means Clustering Algorithm for Fuzzy Rule Base

To infer the difficulties of English news articles by employing the fuzzy inference mechanism based on the percentage of vocabulary occurring in various GEPT grading levels, the used input linguistic variables of the fuzzy inference mechanism are first established herein. In this work, the membership functions used in the fuzzy rule base must be logically determined in advance. The K-means clustering algorithm (Rui & Wunsch, 2005) was applied to determine the centers of the triangle fuzzy membership functions automatically according to the data distribution of the percentage of vocabularies occurring in the gathered English news articles herein. To obtain simple fuzzy rule base for inferring the difficulty of an English news article, this study sets the number of clusters in the K-means clustering algorithm as three. In other words, each considered grading level of occurring vocabulary contains three linguistic terms, i.e. low, moderate, and high, to describe a fuzzy rule. After that, the membership functions of the triangle fuzzy sets were automatically determined according to the cluster centers of three grading levels. Suppose the determined centers of three linguistic terms are assigned notations as c_1, c_2 and c_3 for the vocabulary of elementary level. Figure 3 shows an example for the determined fuzzy membership functions of elementary level.

In addition, the output variable of the fuzzy inference mechanism is the difficulty of an English news article. To explain the designed fuzzy rule base, the simplified representation notations of the input and output linguistic variables are listed in Tables 1 and 2, respectively. Moreover, the defined membership functions for the difficulty of an English news article are shown as Fig. 4.

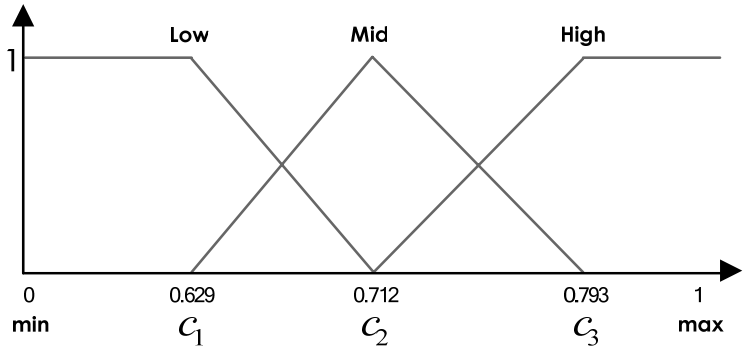

Figure 3. An example of the fuzzy membership functions determined by the centers of three linguistic terms for the elementary level

Table 1. The input linguistic variable for three grading levels of vocabularies

Linguistic variable	Representation method
Lowly occurring percentage of vocabulary	Low
Moderately occurring percentage of vocabulary	Mid
Highly occurring percentage of vocabulary	High

Table 2. The output linguistic variable for the difficulty of an English news article

Linguistic variable	Representation method
Very Lowly Difficult Degree	VL
Lowly Difficult Degree	L
Moderately Difficult Degree	M
Highly Difficult Degree	H
Very Highly Difficult Degree	VH

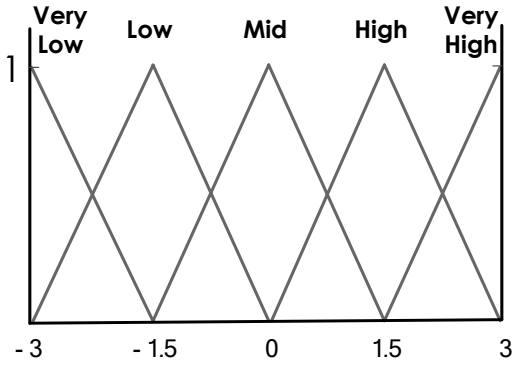

Figure 4. The defined membership functions for the difficulty of an English News article

(3) Designing Fuzzy Rule Base for Inferring the Difficulty of an English News Article

By analyzing the percentage of vocabulary occurring in three various grading levels of GEPT, twenty-seven basic fuzzy rules can be summarized to infer the difficulty of an English news article for the learned English news. Table 3 illustrates the fuzzy rule base designed by English course experts for inferring the difficulty of a piece of English news article.

Table 3. The fuzzy rule base designed by English course experts for inferring difficulty of an English news article

Rule number	Antecedent part						Consequent part	
1	E .Low	∩	I .Low	∩	HI .Low	⇒	D .VL
2	E .Low	∩	I .Low	∩	HI .Mid	⇒	D .VL
3	E .Low	∩	I .Low	∩	HI .High	⇒	D .L
4	E .Low	∩	I .Mid	∩	HI .Low	⇒	D .VL
5	E .Low	∩	I .Mid	∩	HI .Mid	⇒	D .L
6	E .Low	∩	I .Mid	∩	HI .High	⇒	D .L
7	E .Low	∩	I .High	∩	HI .Low	⇒	D .L
8	E .Low	∩	I .High	∩	HI .Mid	⇒	D .L
9	E .Low	∩	I .High	∩	HI .High	⇒	D .H
10	E .Mid	∩	I .Low	∩	HI .Low	⇒	D .VL
11	E .Mid	∩	I .Low	∩	HI .Mid	⇒	D .M
12	E .Mid	∩	I .Low	∩	HI .High	⇒	D .H
13	E .Mid	∩	I .Mid	∩	HI .Low	⇒	D .VL
14	E .Mid	∩	I .Mid	∩	HI .Mid	⇒	D .H
15	E .Mid	∩	I .Mid	∩	HI .High	⇒	D .H
16	E .Mid	∩	I .High	∩	HI .Low	⇒	D .VL
17	E .Mid	∩	I .High	∩	HI .Mid	⇒	D .M
18	E .Mid	∩	I .High	∩	HI .High	⇒	D .VH
19	E .High	∩	I .Low	∩	HI .Low	⇒	D .L
20	E .High	∩	I .Low	∩	HI .Mid	⇒	D .L
21	E .High	∩	I .Low	∩	HI .High	⇒	D .H
22	E .High	∩	I .Mid	∩	HI .Low	⇒	D .L
23	E .High	∩	I .Mid	∩	HI .Mid	⇒	D .H
24	E .High	∩	I .Mid	∩	HI .High	⇒	D .VH
25	E .High	∩	I .High	∩	HI .Low	⇒	D .VL
26	E .High	∩	I .High	∩	HI .Mid	⇒	D .L
27	E .High	∩	I .High	∩	HI .High	⇒	D .M

Note: The notations E, I, HI represent respectively the input variables of elementary level vocabulary, intermediate level vocabulary, high-intermediate level vocabulary, and D is the difficulty of an English news article.

(4) Fuzzy Inference for Inferring the Difficulty of an English News Article

This section explains how to infer the difficulty of an English news article according to the designed fuzzy rule base by fuzzy inference. The designed fuzzy production rules are formed by IF-THEN rules represented as follows:

$$IF \quad X_1 = A_1 \quad and \quad X_2 = A_2 \quad and \quad X_3 = A_3 \quad THEN \quad Y = B$$

where X_i and Y denote linguistic variables, and A_i and B represent linguistic terms.

A defuzzification process aims to convert the outcome of fuzzy inference into a crisp value of difficulty. In the fuzzy set theory, the center of gravity (COG) (Lin & George Lee, 1996), which is most widely used defuzzification scheme, calculates the crisp value of difficulty from the most typical values and respective degrees of membership function. Therefore, the defuzzification method of center of gravity is utilized to obtain the crisp value of difficulty of an English news article, and the mathematical formula is shown as follows:

$$ID = \frac{\int \mu_z(z_j) z_j dz_j}{\int \mu_z(z_j) dz_j} \approx \frac{\sum_{j=1}^{n} \mu_z(z_j) z_j}{\sum_{j=1}^{n} \mu_z(z_j)} \tag{3}$$

where ID is the inferred difficulty of an English news artcile, n is the number of quantization levels of the output; z_j denotes the amount of control output at the quantization level j, and $\mu_z(z_j)$ represents its membership degree in the output fuzzy set Z.

Finally, the final difficulty of an English news article is a linear combination of the normalized RE value measured by Flesch's reading ease formula and the inferred difficulty of an English news article with an adjustable weight assigned to each parameter, and formulated as follows:

$$\text{Final Difficulty} = w \times \text{RE}' + (1 - w) \times \text{ID} \tag{4}$$

where the RE' represents the normalized RE value, ID is the inferred difficulty of an English news artcile, and w is an adjustable weight.

Table 4. The content statistics for a piece of English news article entitled "Chen Considers Control Yuan Head"

Chen Considers Control Yuan Head	
The total number of sentences	14
The total number of vocabularies	311
The total number of syllables	559
The percentage of elementary level vocabulary	0.655
The percentage of intermediate level vocabulary	0.106
The percentage of high-intermediate level vocabulary	0.062
The percentage of the other vocabularies	0.177

An Example for Inferring the Difficulty of a Piece of English News Article

This section gives an example to explain how to infer the difficulty for a piece of English news article in detail. Suppose Table 4 illustrates the content statistics for a piece of English news article entitled "Chen Considers Control Yuan Head". Next, the detailed procedures for inferring the difficulty of this English news article are described as follows:

Computing the RE value of the English news article by Flesch's reading ease formula

$$\begin{aligned} \text{RE} &= 206.835 - (1.015 \times \text{ASL}) - (84.6 \times \text{ASW}) \\ &= 206.835 - (1.015 \times \frac{311}{14}) - (84.6 \times \frac{559}{311}) \\ &= 32.262 \end{aligned} \tag{5}$$

Normalizing the RE value by Eq. (2)

$$\begin{aligned} RE' &= RE \times (\frac{-6}{100}) + 3 \\ &= 32.262 \times (\frac{-6}{100}) + 3 \\ &= 1.064 \end{aligned} \quad (6)$$

Computing the difficulty of the English news article by fuzzy inference

The percentages of the used vocabularies for three considered grading levels in this English news article are 0.655, 0.106, and 0.062, respectively. Eight fuzzy rules including rule numbers of 2, 3, 5, 6, 11, 12, 14, and 15 in the fuzzy rule base are triggered for inferring the difficulty. Figure 5 shows the triggered consequent parts of output variable for defuzzification. Here, the defuzzification strategy of center of gravity (COG) (Lin & George Lee, 1996) is employed to convert the outcome of fuzzy inference into a crisp value, and computed as follows:

$$\begin{aligned} ID &= \frac{\sum_{j=1}^{n} \mu_z(z_j) z_j}{\sum_{j=1}^{n} \mu_z(z_j)} \\ &= \frac{0.206 \times (-3) + 0.694 \times (-1.5) + ... + 0.305 \times 1.5 + 0 \times 3}{0.206 + 0.694 + ... + 0.305 + 0} \\ &= -0.547 \end{aligned} \quad (7)$$

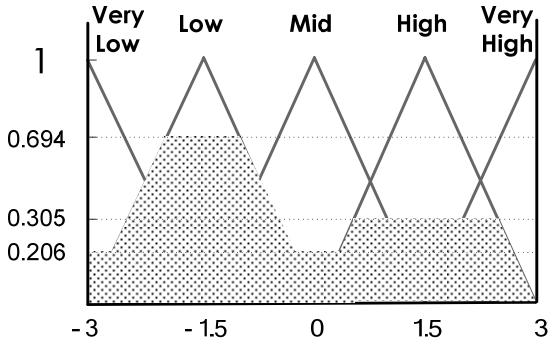

Figure 5. The triggered consequent parts of output variable for defuzzification

Determining the final difficulty of the English news article by integrating the normalized RE and the inferred difficulty value under the adjustable weight is set to 0.5

$$\begin{aligned} \text{Final Difficulty} &= 0.5 \times 1.064 + 0.5 \times (-0.547) \\ &= 0.259 \end{aligned} \quad (8)$$

Personalized English News Recommendation

Estimating learner reading ability enables the system to recommend the appropriate English news articles to learners. The personalized courseware recommendation agent estimates learner reading ability using the proposed fuzzy Item Response Theory (FIRT), then calculates the information function values of English news articles to recommend appropriate English news articles to individual learners based on the ranking order of information function values of English news articles. The following subsections first describe how to evaluate learner's reading ability and recommend appropriate English news articles to individual learners based on the FIRT in detail.

Courseware Modeling and Estimation of Learner's Reading Ability

To estimate learner's reading ability, the item characteristic function with a single difficulty parameter proposed by Rasch (Baker, 1992) is first used to model a piece of English news article. The formula of item characteristic function with single difficulty parameter is formulated as follows:

$$P_j(\theta) = \frac{e^{D(\theta - b_j)}}{1 + e^{D(\theta - b_j)}} \tag{9}$$

where $P_j(\theta)$ denotes the probability that learners can completely understand the j^{th} English news article at a level below their ability level θ, b_j is the difficulty of the j^{th} English news article, and D is a constant 1.702.

Two methods are widely used in assessing learner's ability in computerized adaptive testing (CAT) field. They are the maximum likelihood estimation (MLE) and Bayesian estimation approaches (Baker, 1992). Although the procedure of MLE is simple and easily implemented, it has the problem of producing divergent estimations for learner's ability when the learner gives complete understanding or not understanding responses for all learned courseware during a learning process. The Bayesian estimation procedure always converges for all possible learners' responses (Baker, 1992). For this reason, the Bayesian estimation procedure is applied to estimate learner's reading ability in this study. Bock and Mislevy (Baker, 1992) derived the quadrature form to approximately estimate learner's ability as follows:

$$\hat{\theta} = \frac{\sum_{k}^{q} \theta_k L(u_1, u_2, ..., u_n \mid \theta_k) A(\theta_k)}{\sum_{k}^{q} L(u_1, u_2, ..., u_n \mid \theta_k) A(\theta_k)} \tag{10}$$

where $\hat{\theta}$ denotes the learner's reading ability of estimation, $L(u_1, u_2, \cdots, u_n \mid \theta_k)$ is the value of likelihood function at a level below their ability level θ_k and learner's responses are $u_1, u_2, ..., u_n$, θ_k is the k^{th} split value of ability in the standard normal distribution, and $A(\theta_k)$ represents the quadrature weight at a level below their ability level θ_k.
In Eq. (10), the likelihood function $L(u_1, u_2, \cdots, u_n \mid \theta_k)$ can be further described as follows:

$$L(u_1, u_2, \cdots, u_n \mid \theta_k) = \prod_{j=1}^{n} P_j(\theta_k)^{u_j} Q_j(\theta_k)^{1-u_j} \tag{11}$$

where $P_j(\theta_k) = \frac{e^{D(\theta_k - b_j)}}{1 + e^{D(\theta_k - b_j)}}$, $Q_j(\theta_k) = 1 - P_j(\theta_k)$, $P_j(\theta)$ denotes the probability that learners can understand the j^{th} English news article at a level below their ability level θ_k, $Q_j(\theta_k)$ represents the probability that learners cannot understand the j^{th} English news article at a level below their ability level θ_k, and U_j is the completely understanding or not understanding answer obtained from learner feedback to the j^{th} English news article, i.e. if the answer is completely understanding then $U_j = 1$; otherwise, $U_j = 0$.

In the system presented here, learner reading abilities are restricted to between –3 and 3. That is, learners with reading ability $\theta = -3$ are classified as the poorest, those with ability $\theta = 0$ are considered to have moderate abilities, and those with ability $\theta = 3$ are regarded as having the best abilities. This system adjusts learners' reading abilities based on learner feedback responses. However, the Bayesian estimation procedure estimates learner reading ability merely through learner's crisp responses. It cannot estimate learner reading ability through learner's fuzzy responses. To solve this limitation, the FIRT derived from the original IRT is presented herein. The proposed FIRT can infer learner reading ability based on the replies to two predefined simple questionnaires, which are collected by the feedback agent. In this approach, the fuzzy inference mechanism (Lin & George Lee, 1996) is applied to infer the understanding degree according to the learner's feedback responses. Based on the evaluation of understanding degree explained in a later subsection, the learner's reading ability after learning an English news article can be evaluated as follows:

$$\theta_{j+1} = \begin{cases} \theta_j + (\theta_w - \theta_j) \times u & when \quad 0 \le u < 0.45 \\ \theta_j & when \quad 0.45 \le u \le 0.55 \\ \theta_j + (\theta_c - \theta_j) \times u & when \quad 0.55 < u \le 1 \end{cases} \tag{12}$$

where θ_j denotes the estimation value of the learner's reading ability for the total number of j accumulatively learned English news articles, θ_{j+1} represents the estimation value of the new learner's reading ability after learning the $(j+1)^{th}$ English news article, θ_w is the estimation value of the learner's reading ability assuming that the learner cannot completely understand the $(j+1)^{th}$ English news article, θ_c denotes the estimation value of the learner's reading ability assuming that the learner can completely understand the $(j+1)^{th}$ English news article, and u represents the understanding degree inferred by the fuzzy inference mechanism for the $(j+1)^{th}$ English news article.

Using the estimation method of learner's reading ability mentioned in Eq. (12), if the learner's understanding degree inferred by the fuzzy inference mechanism ranges between zero and 0.45, then the result indicates that the learner cannot understand the greater part of the contents of the learned English news article. Therefore, the learner's reading ability in the learned English news should be descended. That is, he/she needs to learn easier English news articles in order to promote his/her basic knowledge in the learned English news article. Moreover, if the learner understanding degree inferred by the fuzzy inference mechanism is between 0.45 and 0.55, then the result indicates that the learner gives a highly uncertain feedback response. Thus, the learner's reading ability after reading the learned English news articles has not been tuned. On the other hand, if the learner's understanding degree inferred by the fuzzy inference mechanism is between 0.55 and 1, then the result denotes that the learner can understand the most part of contents of the learned English news article. Thus, the learner's reading ability after reading the learned English news articles should be promoted. After evaluating the new learner's reading ability, the system will evaluate the information function values of all gathered English news articles based on the maximum information approach to find out the most appropriate English news articles for the individual learner.

Inference of Understanding Degree

To infer the learner understanding degree by employing the fuzzy inference mechanism according to the learner's feedback responses, the used input linguistic variables of the fuzzy inference mechanism are established herein. The variables include the feedback agent's collection of English news article on the difficulty level and the comprehension percentage for the learned English news article. Besides, the output variable of the fuzzy inference mechanism is the understanding degree of the learned English news article. To explain the designed fuzzy knowledge base, the simplified representation notations of the input and output linguistic variables are listed in Tables 5 and 6, respectively. Moreover, the bell-shaped membership function is then applied to describe the linguistic variables of input and output for the fuzzy inference mechanism. The bell-shaped membership function can be formulated as follows:

$$\mu_{x_i}(x) = e^{\left(\frac{-(x-m_i)^2}{2\sigma_i^2}\right)} \tag{13}$$

where $\mu_{x_i}(x)$ denotes the fuzzy degree of the input x under the linguistic variable x_i, m_i and σ_i specify the mean and the width of the bell-shaped membership function for the linguistic variable x_i, respectively. The used membership functions of input and output linguistic variables are shown as Figs. 6, 7 and 8.

By analyzing the results of the learner's feedback responses, nine basic fuzzy rules can be summarized to infer the learner's understanding degree for the learned English news article. Table 7 illustrates the designed fuzzy rule base for the proposed fuzzy Item Response Theory. To infer the learner's understanding degree, the reasoning process of Mandani's minimum fuzzy implication (Lin & George Lee, 1996) is employed to integrate the triggered fuzzy rules. Moreover, the defuzzification method of center of gravity (Lin & George Lee, 1996) is used to obtain the crisp value of learner's understanding degree in order to evaluate learner's reading ability herein.

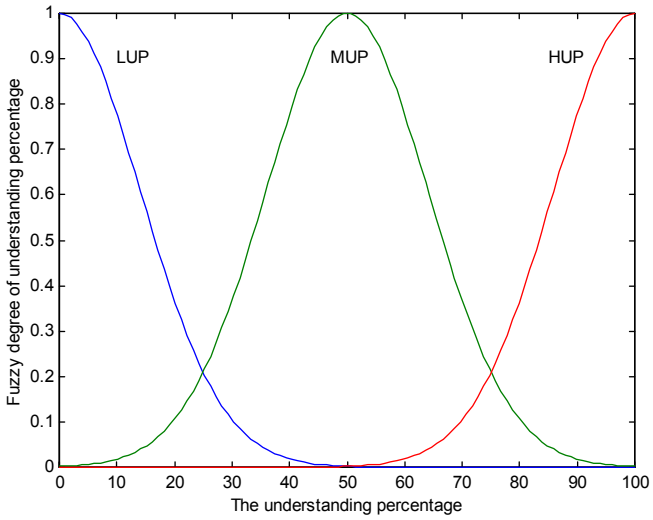

Figure 6. The membership functions for the comprehension percentage of reading

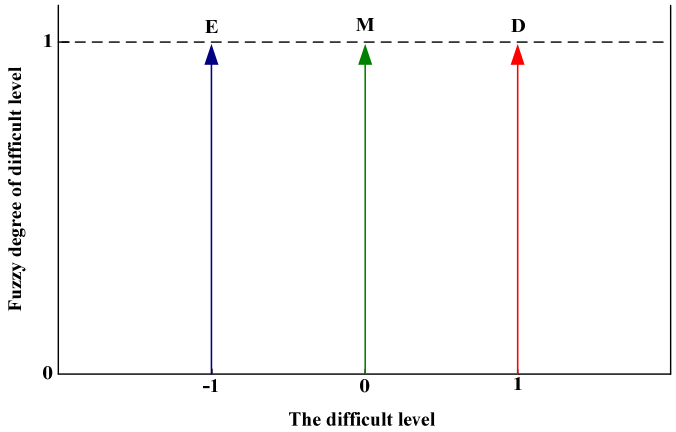

Figure 7. The membership functions of fuzzy singleton for the difficulty level of reading English news article

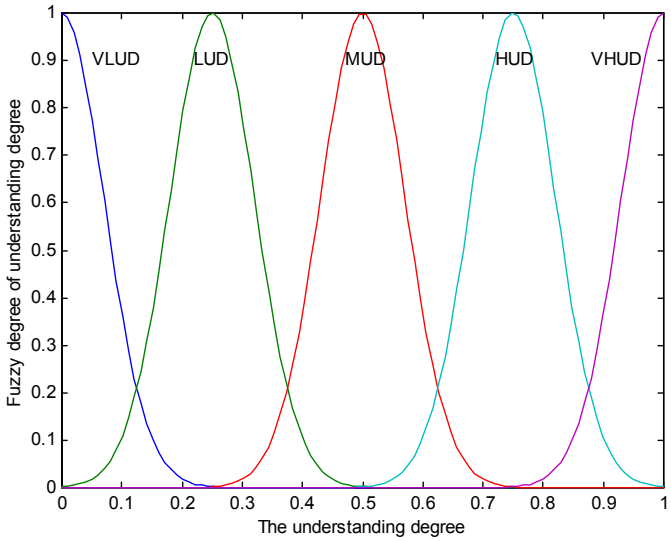

Figure 8. The membership functions for the learner understanding degree

Table 5. The input linguistic variables for the comprehension percentage of reading and the difficulty level

Linguistic variable for the comprehension percentage of reading	Representation method	Linguistic variable for the difficulty level	Representation method
Lowly understanding percentage	LUP	Easy	E
Moderately understanding percentage	MUP	Moderately	M
Highly understanding percentage	HUP	Hard	H

Table 6. The output linguistic variable for the learner understanding degree

Linguistic variable	Representation method
Very Lowly Understanding Degree	VLUD
Lowly Understanding Degree	LUD
Moderately Understanding Degree	MUD
Highly Understanding Degree	HUD
Very Highly Understanding Degree	VHUD

Table 7. The designed fuzzy rule base for inferring learner's understanding degree of the learned English news article

Understanding degree		The understanding percentage of reading		
		LUP	MUP	HUP
The difficulty level of reading English news article	E	MUD	HUD	VHUD
	M	LUD	MUD	HUD
	H	VLUD	LUD	MUD

Maximum Information Evaluation and English News Recommendation

In traditional IRT, two approaches are used to recommend appropriate courseware to the learner. They are the maximum information strategy and Bayesian strategy (Baker, 1992), respectively. Maximum information strategy emphasizes that each English news article with the corresponding difficulty parameter exhibits different information to learner's reading. English news article with higher-information is more suitable to be recommended for the learner. Since the Bayesian strategy is more complicated than the maximum information approach, the maximum information method is applied to recommend appropriate English news article for the proposed FIRT. The maximum information function is defined as follows:

$$I_j(\theta) = \frac{(1.7)^2}{\left[e^{1.7(\theta - b_j)}\right]\left[1 + e^{-1.7(\theta - b_j)}\right]^2} \tag{14}$$

where $I_j(\theta)$ is the information function value of the j^{th} English news article at a level below their ability level θ, b_j is the difficulty parameter of the j^{th} English news article.

After calculating the corresponding information values of English news articles, the personalized courseware recommendation agent can recommend a series of English news articles to the learner with reading ability θ according to the ranking order of information function values. An English news article with the maximum information function value under learner with reading ability θ indicates that the system presented here gives the highest recommendation priority. Whether the learner accepts the recommended English news article with highest recommendation priority or selects the other recommended courseware to do further reading, our system will record learner's reading paths and learner's feedback responses into the remote courseware & user portfolio database during learning processes.

Personalized English Vocabulary Recommendation

Since the key factor affecting the reading ability of English news article is often vocabulary ability, how to promote the reading ability of English news article through increasing vocabulary ability is also a key issue herein.

Moreover, learners have different vocabulary abilities and memory cycles for various vocabularies based on their prior knowledge. This PIMS system employed the personalized English vocabulary recommendation agent to correctly identify new or unfamiliar vocabularies of individual learners from the reading English news article in order to enhance vocabulary abilities of individual learners. In this work, another proposed personalized vocabulary learning system (Chen & Chung, 2006) is used to support the personalized English vocabulary recommendation agent in order to measure the vocabulary abilities of individual learners, identify the memory cycles of individual learners for various vocabularies, and provide a personalized vocabulary learning mechanism. In the meanwhile, the personalized vocabulary learning system can also measure the difficulty of vocabulary based on considering the GEPT grading level of vocabulary, the length of vocabulary, and the ratio of the number of characters to the length of phonetic symbols. The range of the difficulty of vocabulary measured by the personalized vocabulary learning system is normalized between -3 to +3, which is the same with the range of the learner's vocabulary ability. Here, the PIMS system adopts the difficulty parameters of vocabularies from the personalized vocabulary learning system to identify whether the vocabularies appearing in the reading English news article are new or unfamiliar vocabularies to the learner by comparing the difficulties of vocabularies with the vocabulary abilities of individual learners. In the study, if the difficulty parameters of the appeared vocabularies in the learned English news article are larger than the current learner vocabulary ability evaluated by the personalized vocabulary learning system, then the corresponding English vocabularies will be served as likely new vocabularies to the learner. Therefore, the set R_{ij} of the recommended vocabularies for individual learners can be represented as follows:

$$R_{ij} = (C_j \cap A_i) - L_i \tag{15}$$

where R_{ij} represents the set of the recommended new or unfamiliar vocabularies contained in the j^{th} English news article for the i^{th} learner, A_i is the set of vocabularies that the corresponding difficulty parameters are higher than the i^{th} learner's vocabulary ability, C_j is the set of all vocabularies contained in the j^{th} English news article, L_i is the set of the acquired vocabularies of the i^{th} learner.

Experiments

This section first introduces the implemented personalized intelligent mobile learning system on PDA for English news reading learning. Moreover, to demonstrate the learning effectiveness of the proposed system for English news reading learning, some university students were invited to participate in the experiment during five weeks. The experimental environment and results are detailed and analyzed as the following subsections.

The System Implementation

Gathered English News Articles and Courseware Management System

The detailed procedures of English news archive have been mentioned in previous section. This study also developed a courseware management system with functionality of English news archive in the server side. Currently, there are totally 2792 news articles stored in the remote courseware & user portfolio database, which can support effectively English news reading learning. Moreover, Fig. 9 shows the difficulty distributions of 2792 archival English news articles evaluated by the proposed difficulty assessment agent of English news. The difficulty parameters of these gathered English news articles are distributed from –1.70 to +2.68. This uniform distribution of difficulty parameters is helpful to recommend appropriate English news article to learners with different English news reading abilities. In Fig. 9, the news article with difficulty level –3 stands for the easiest one, the news article with difficulty level 0 represents the moderate one, and the news article with difficulty level + 3 indicates the most difficult one. The results indicate that the gathered English news articles are towards more difficult than general English articles used in daily lives. Therefore, the gathered English news articles are not suitable for reading learning to learners with poor English ability. In our experiments, there are totally 47 English news articles selected as course materials by an experienced English teacher for English news reading learning during five weeks. In order to recommend appropriate English news article to learners with different English news reading abilities, the difficulty parameters of these selected English news articles are averagely distributed from –1.70 to +2.68.

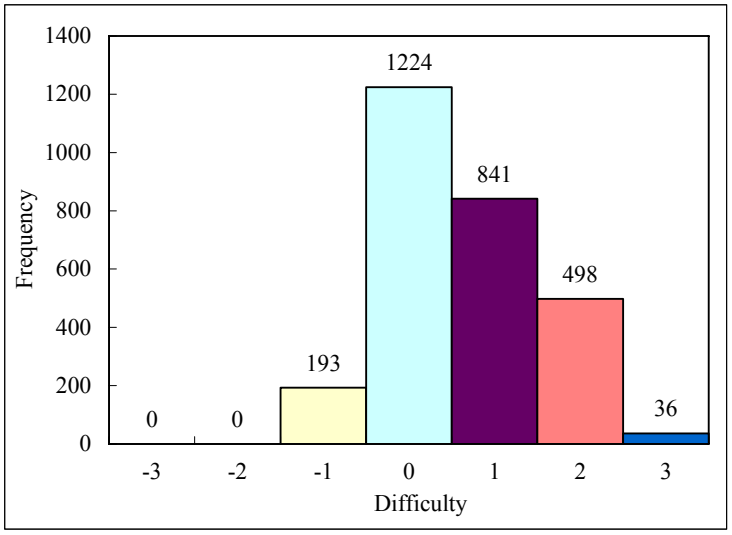

Figure 9. The difficulty distributions of the archival English news articles

The Designed System Interface

This section details the PIMS system implemented by the developing tool of Microsoft Visual Studio .NET 2003. Figure 10 shows the designed PDA learning interface. First, the learning interface agent gets the titles of English news articles from the local client courseware database and exhibits them to learners if they use legal accounts to login the system. Figure 10(a) displays the list of all English news titles stored in the local client courseware database. After a learner clicks some English news title, the learning interface agent will get the content of the clicked English news article from the local client courseware database and exhibits them to the learner. Figure 10(b) shows the learning content of the clicked English news article and the designed learning feedback interface for learners. In addition, Fig. 10(c) reveals the corresponding Chinese translation of a selected paragraph in a learned English news article. Many scholars argued that providing the translation enhances L2 reading (Cook, 1992; Krashen, 1981), but some researches proposed that reading in an L2 is not a monolingual event and the cognitive influence of one's L1 on L2 acquisition has been clearly shown (Upton & Lee-Thompson, 2001; Cohen, 1995). Kern's (1994) study proposed that L2 readers often access to their L1 and use this resource as a strategy to help them comprehend an L2 text. Upton & Lee-Thompson's study (2001) also indicated that the mental translation defined by Kern (1994) as the "mental reprocessing of L2 words, phrases, or sentences in L1 forms while reading L2 texts" is a variable that influences reading comprehension.

Kern's study (1994) also found that L2 readers most frequently used mental translation in response to specific obstacles to comprehension, such as unfamiliar words and structures. Additionally, Krashen's research (1981) concluded that L1 may "substitute" for the acquired L2 as an utterance initiator when the performer has to produce in the target language, but has not acquired enough of the L2 to do this. Therefore, to avoid reading obstacles during learning processes, each piece of English news article was partitioned into several small paragraphs and each paragraph has a corresponding Chinese translation. This function aims at helping learners to assess whether their reading comprehension is correct after they read a selected paragraph in an English news article. In the meanwhile, looking up the corresponding Chinese translation function is optional, thus it can be determined based on learner self-requirement. In addition, the client mobile learning system can extract the unfamiliar or new vocabularies to individual learners according to the learners' vocabulary abilities measured by the personalized vocabulary learning system (Chen & Chung, 2006) for English vocabulary learning. Figure 10(d) reveals the list of these likely new vocabularies identified by the personalized vocabulary learning system with the corresponding Chinese translations for the learned English news article. Moreover, Fig. 10(e) exhibits the checking interface of vocabularies for confirming the acquired vocabularies of individual learners. Finally, the client mobile learning system will re-evaluate learners' reading abilities according to the explicit feedback responses of the learned English news articles, then recommend appropriate English news articles to individual learners for the next learning cycle. Figure 10(f)

shows the list of the recommended English news articles ranked by the reading priority order for the next learning cycle.

(a) The list of English news titles

(b) The learning contents of the clicked English news article and the designed feedback interface for learners

(c) The corresponding Chinese translations for the learned English news article

(d) The list of likely new vocabularies identified by the system with the corresponding Chinese translations

(e) The checking interface of the acquired vocabularies

(f) The list of the recommended English news articles ranked by the reading priority order for the next learning cycle

Figure 10. The designed user interface of the personalized intelligent mobile learning system

Research Target and Limitations

In order to assess the learning performance of the proposed personalized intelligent mobile learning system, this study called a class meeting to recruit fifteen third grade university students who were majoring in the Department of English Teaching at National Hualien University of Education to take part in this experiment according to their willingness. In this class meeting, the researchers of the study first gave an oral presentation to explain the research background, motivations, and experimental procedure of the study, and then exhibited the functionalities of the implemented PIMS on PDA device. After that, this study recruited fifteen volunteers from thirty-five students who attended the meeting. Among fifteen participants, there are two male students and thirteen female students, their first language is Chinese, and their ages are between twenty-one to twenty-three years old. Adopting fifteen participants to conduct this experiment is due to the limitation of the number of high price PDA equipment. Therefore, the experimental results mentioned later are not suitable to be broadly inferred or explained to the other cases since this study only adopted small samples. In addition, fifteen participants had no or very minimal experience on using PDA devices before participating in the experiment. This situation could lead to learning obstacle while operating PDA for reading learning. Moreover, all participants were being trained to be an English teacher of elementary school in their university careers. Thus, they had been educated basic teaching skills of English listening, speaking, reading and writing for three years at least. Since all participants were volunteers and were majoring in English teaching department, they were highly interested in using the novel learning tool for English reading learning, thus owning high learning motivations. Additionally, the learning activity of English news reading only provided static articles displayed on PDA for learners' reading learning without any listening comprehension functions. Therefore, reading learning of English news articles assisted by news announcer pronunciation has not yet been considered in the study.

Experimental Design

The designed experimental procedure for learning performance assessment is displayed as Fig. 11. The testing sheets of pre-test and post-test, which contain respectively ten choice questions of reading test from ten randomly selected English news articles, were designed by an experienced English teacher for the learning performance assessment. The testing sheets of pre-test and post-test were examined by statistical analysis to confirm owning the same difficulty level. The testing time of the reading test is fifty minutes for both the pre-test and post-test.

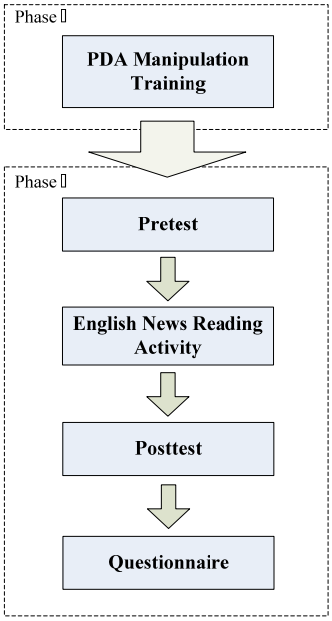

Figure 11. The procedure of the experiment

Before performing the experiment, fifteen participants received the training course of two hours to operate PDA and used the proposed PIMS system, and then they were invited to perform a pre-test for assessing their initial English news reading abilities. The circumstance of the PDA operation training and the pre-test in a computer classroom are

exhibited as Figs. 12(a) and 12(b), respectively. After finishing the training course and the pre-test, each learner was distributed a PDA to perform English news reading learning by the proposed PIMS system during five weeks. In other words, the learners can freely use this handheld system at anytime and anywhere for conducting ubiquitous reading learning of English news articles. In the meanwhile, the proposed system can immediately monitor learners' learning states via the recorded learning portfolios during learning processes. Teachers can also observe the recorded learning portfolios through the user interface of the courseware management system. When a learner never login the system for English reading learning within two days, the proposed system will send an e-mail letter to remind his/her learning states. Five weeks later, these fifteen students were invited to perform a post-test for assessing their English news reading abilities and fill out a pre-designed questionnaire for evaluating their satisfactory degree after learning.

(a) PDA operation training (b) The pre-test of English news reading ability

Figure 12. The training course for PDA operation training and pre-test in a computer classroom

Learning Evaluation

In this section, three evaluating procedures including a pre-test, post-test, and questionnaire were performed to assess the learning outcomes for the proposed PIMS system.

Learning Performance Evaluation

Figure 13 displays the comparison results of the learning performance for both the pre-test and post-test. The post-test results indicated that 15 participants' language abilities prior to starting the reading learning activity have obvious difference. To encourage us is that the learning performances of most learners in the post-test are better than the pre-test except the number 05 learner. To analyze the reason, the study found that the number 05 learner had not conducted the post-test with the other fourteen learners together. Hence, she was invited to perform the post-test alone. We observed that she could not concentrate her attention on the post-test and only conduct the post-test about twenty minutes due to unclear mental or personal factors. This may lead to very poor post-test score. Based on the reason, the post-test score of the number 05 learner was served as noise sample, thus was eliminated from our statistical analysis. In addition, Fig. 14 shows the variation curves of reading abilities against learning times for three observing learners with low, moderate, and high reading abilities during the learning process. The experimental results indicate that the promotion speed of reading ability of the learner 02 with low reading ability is slower than the other two learners with moderate, and high reading abilities during the learning process. By contrast, compared with the other two learners with low, and moderate reading abilities, the promotion speed of reading ability of the learner 07 with high reading ability is the fastest one. Importantly, the reading abilities of learners will be descended when learners cannot understand the recommended news articles due to over high difficulty parameter to them until their reading abilities are promoted by the proposed personalized reading learning strategy. However, our experimental results show that three observing learners with different initial reading abilities before learning gradually approach to the same reading ability after performing about the 31th learning times. The result shows that the proposed PIMS can recommend appropriate news articles to individual learners, thus promoting learners' reading abilities regardless of their initial reading abilities.

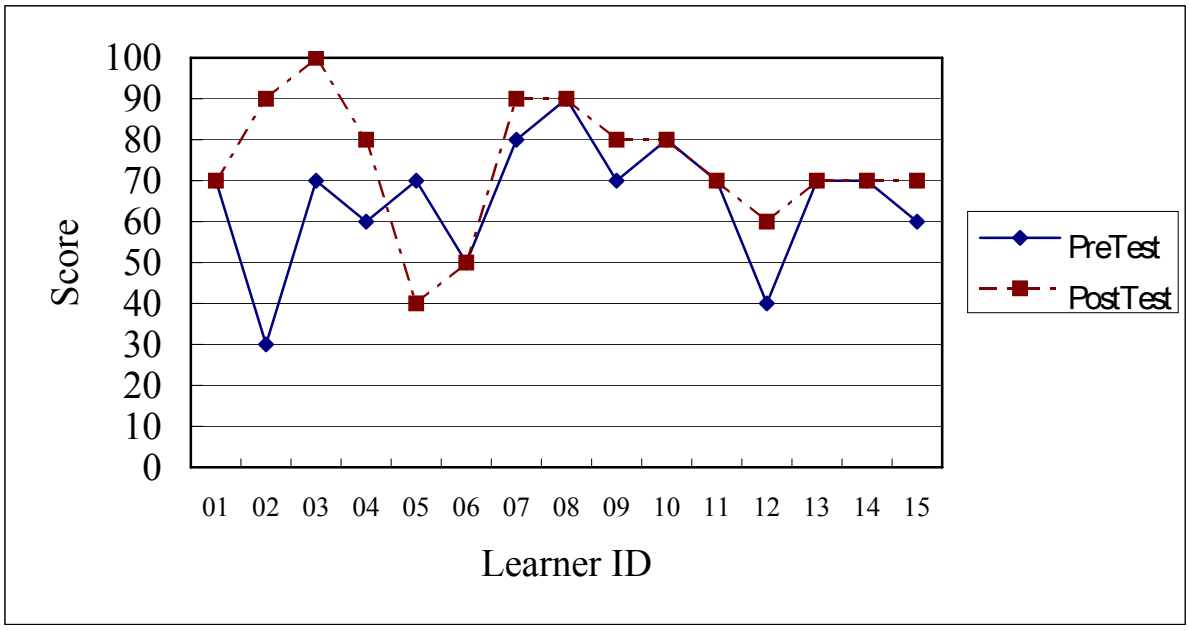

Figure 13. The comparisons of learning performance for both the pre-test and post-test scores

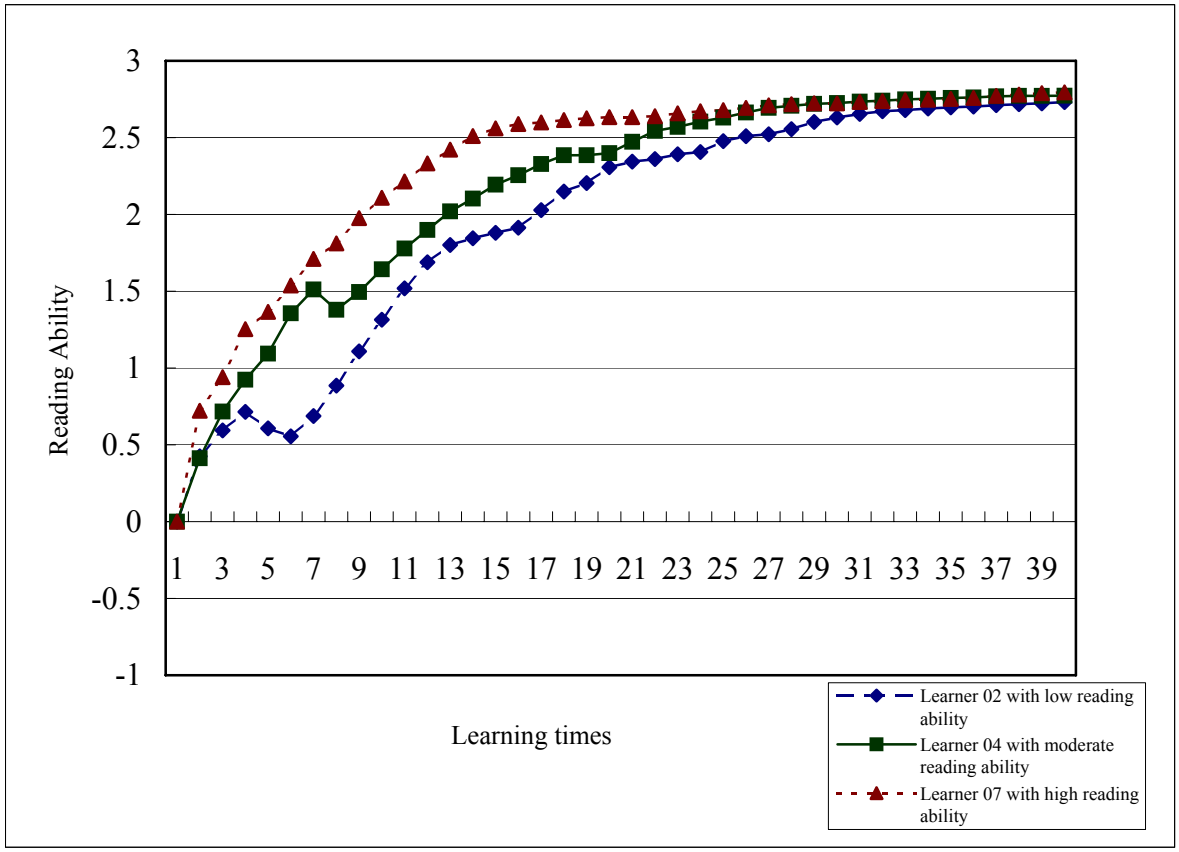

Figure 14. The variation curves of reading abilities against learning times for three observing learners with low, moderate, and high reading abilities during the learning process

In order to compare the difference of the English news reading abilities of the learners before and after learning by the proposed PIMS system, SPSS statistical software was used to analyze the results of the pre-test and post-test. Table 8 lists the paired sample statistics information for both the pre-test and post-test (N = 14). As the results of descriptive statistics listed in Table 8, the mean scores of fourteen learners for both the pre-test and post-test are 65 and 76.4, respectively. In the meanwhile, the standard deviation of fourteen learners for both the pre-test and post-test are 16.05 and 13.36, respectively. Table 9 gives the trial results of the paired sample t-test of the pre-test and post-test scores. This study found that the difference of the mean scores between the pre-test and post-test scores is -11.43, the trial results reach the significant level under the degree of freedom is set to 13 (i.e. $t = -2.51$, $p = .026$). In other words, after using the proposed PIMS system, the promotion of learners' learning performances achieves significant level and the mean testing score increases 11.43 points.

Table 8. The paired sample statistics information for both the pre-test and post-test scores (N = 14)

	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Pretest	65	14	16.05	4.29
Posttest	76.4	14	13.36	3.57

Table 9. The paired sample t-test for both the pre-test and post-test scores

	Paired Differences					**t**	**df**	**Sig. (2-tailed)**
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
				Lower	**Upper**			
Pretest - Posttest	-11.43	17.03	4.55	-21.26	-1.59	-2.51	13.00	.026

Moreover, in order to understand whether the proposed PIMS system provides different learning performances for learners with various English reading abilities, the K-means clustering scheme (Margaret, 2002) was employed to group all learners into three clusters based on their pre-test scores. Table 10 illustrates the cluster results based on the pre-test scores of learners. Additionally, Table 11 shows the statistical information of three cluster groups. This study found that the low score group has best learning performance than the other two groups regardless of the average amount of reading articles, the average amount of learning vocabularies, or the average progressive score. In other words, the PIMS system provides the most benefit in terms of learning performance promotion for the low score learners in this study.

Table 10. The cluster results based on the pre-test scores of learners

Item / Group	Learner ID	Mean Score
High Score Group	Learner 07, Learner 08, Learner 10	83.33
Moderate Score Group	Learner 01, Learner 03, Learner 04, Learner 05, Learner 09, Learner 11, Learner 13, Learner 14, Learner 15	67.78
Low Score Group	Learner 02, Learner 06, Learner 12	40.00

Table 11. The statistical information of three cluster groups

Group / Item	Low Score Group	Moderate Score Group	High Score Group
Average reading amount of English news articles	54.7	25.2	39.7
Average learning amount of vocabularies	57.0	31.9	54.0
Average progressive score	26. 7	4.4	3.3

Questionnaire Analysis

To evaluate learners' satisfaction degrees for the proposed PIMS system, referring to Chen's *et al.* research (Chen *et al.*, 2007), a questionnaire which involves twenty-one questions distinguished five various question types was designed to measure whether the provided services in the proposed PIMS system satisfy the real requirements of

most learners. The five question types contain the personal information about learners' learning by PDA, the convenience of the system operation, the investigation of the learners' learning attitude towards using the proposed learning system, the suggestions from learners' feedback, and the self-assessment of learners' English news reading ability before and after using the proposed PIMS system for learning. Table 12 gives a summarization of the descriptions of question types. The evaluation results of satisfaction degree are listed in Table 13. To conveniently observe the evaluating results, the investigation results of "strongly agreed" and "agreed" are merged as "approved", and the investigation results of "strongly disagreed" and "disagreed" are merged as "disapproved".

Table 12. The descriptions of question types

Question Type	The number of questions	Description
Personal Information about Using PDA	4	To get the personal information about learners who participated in the learning activity.
System Operation	5	Questions related to the user interface and the contents of learning materials.
Learning Attitude	7	To investigate whether the system can enhance learners' learning motivations or interests and promote their learning achievements.
Advantages and Disadvantages of the Proposed System	4	To ask learners for investigating the advantages and disadvantages of the proposed PIMS system.
Self-assessment	1	To ask learners for self-assessing their English news reading abilities before and after using the proposed PIMS system.

Table 13(a) lists the investigation results of the personal information. The evaluating results listed in Table 13(b) indicate that the satisfaction degree of "approved" achieves 81.32% in terms of system operation. Table 13(c) indicates that 75.21% learners satisfy the promotion of learning attitude and interest. Moreover, Table 13(d) lists the investigation results of advantages and disadvantages of the proposed PIMS system. Most learners agreed that the proposed PIMS system provides a friendly user interface, some helpful mechanisms for aiding English news reading learning as well as promotes learning motivations and interests of English reading learning. Particularly, most learners indicated that reading English news article with a corresponding Chinese translation is helpful to promote comprehension degree while reading an English news article. In the meanwhile, learners also proposed several suggestions to enhance the system functions, such as adding a dictionary for looking up unfamiliar vocabularies, English news report with corresponding pronunciation for assisting the training of listening comprehension, and so on.

Table 13. The satisfaction evaluation results of questionnaire

(a) The investigation results of the personal information

Question Type	Question	The Number of Learners	
		Yes	No
Personal Information about Using PDA	Do you or your family have PDA or cell phone with PDA?	2	13
	Do you use PDA first time?	13	2
	Have you ever used PDA for learning?	1	14

(b) The investigation results of the system operation

Question Type	Question	Satisfaction Degree (%)				
		strongly agreed	agreed	no opinion	disagreed	strongly disagreed
System Operation	I agree that the PIMS system provides a friendly user interface.	4(26.7%)	9(60.0%)	0(0.0%)	2(13.3%)	0(0.0%)
	I am very clear about the learning procedure of the PIMS system.	5(33.3%)	9(60.0%)	0(0.0%)	1(6.7%)	0(0.0%)

	I can completely understand the meaning of learning materials recommended by the PIMS system.	2(13.3%)	11(73.3%)	0(0.0%)	2(13.3%)	0(0.0%)
	I think the PIMS system is a beneficial learning tool to assist English learning.	0(0.0%)	10(66.7%)	0(0.0%)	5(33.3%)	0(0.0%)
	I agree that learning English by PDA is very convenient because I can perform English learning at any time and place.	2(13.3%)	9(60.0%)	0(0.0%)	4(26.7%)	0(0.0%)
	Average	**81.32%**		**0%**	**18.66%**	

(c) The investigation results of the learning attitude

Question Type	**Question**	**Satisfaction Degree (%)**				
		strongly agreed	**agreed**	**no opinion**	**disagreed**	**strongly disagreed**
Learning Attitude	I agree that the design learning materials on the PIMS system can promote my learning interests.	0(0.0%)	9(60.0%)	1(6.7%)	4(26.7%)	1(6.7%)
	I often increase my learning time because learning by the proposed PIMS system promotes my learning interests.	2(13.3%)	8(53.3%)	1(6.7%)	4(26.7%)	0(0.0%)
	I think that using the PIMS system can effectively promote my English news reading ability.	3(20.0%)	11(73.3%)	0(0.0%)	1(6.7%)	0(0.0%)
	The self-inspection interface provided by the PIMS system can encourage my learning motivation.	3(20.0%)	8(53.3%)	0(0.0%)	4(26.7%)	0(0.0%)
	I agree that using PDA to learn English is a very interesting learning mode.	2(13.3%)	9(60.0%)	0(0.0%)	4(26.7%)	0(0.0%)
	I agree that the PIMS system can recommend English news articles with appropriate difficult to me.	2(13.3%)	9(60.0%)	1(6.7%)	3(20.0%)	0(0.0%)
	I think that the English news articles with the corresponding Chinese translations are helpful to English news reading learning for Chinese students.	4(26.7%)	9(60.0%)	1(6.7%)	1(6.7%)	0(0.0%)
	Average	**75.21%**		**3.82%**	**20.98%**	

(d) The summarized investigation results from the learners' feedback responses

	Advantage	Disadvantage
Advantages and Disadvantages of the Proposed System	1. The PIMS system provides a friendly learner interface. 2. The PIMS system is helpful to me to know immediate news events except English news reading learning. 3. The PIMS system is conveniently carried for any time and place learning. 4. The PIMS system can promote learning motivations and interests of English learning. 5. Reading English news article with a corresponding Chinese translation is helpful to promote comprehension degree for the reading news article. 6. The self-inspection function of learning processes is helpful to me to understand my learning states and inspire my learning motivation.	1. The adopted English course materials should be more broadly. For example, including English funny stories or English delight articles. 2. English news articles should add the function of news report to assist the training of listening comprehension. 3. After finishing reading learning, the PIMS system can provide the reading test function except self-assessment feedback. This will be more helpful to evaluate reading comprehension degree. 4. The PIMS system should add dictionary function for supporting vocabulary learning. 5. The English news articles that have been read should be remarked or filtered out to avoid repeat learning. 6. The wireless function for connecting with the courseware server is unstable sometime.

Finally, this study also designed a self-assessment question for self-evaluating learners' English news reading abilities of before and after learning. The question asked learners to assess their English news reading abilities before and after learning based on a score with ten different scales. This study also used SPSS statistical software to perform the paired sample t-test in order to evaluate the difference of self-assessing learning performance. Tables 14 and 15 display the paired sample statistics and the paired sample t-test results of the self-assessing English news reading abilities of learners before and after learning, respectively. The paired sample t-test results show that the difference of learning performance reaches significant level (i.e. $t = -6.25$, $p = .000$). That is, most learners thought that their reading abilities of English news are obviously promoted after using the PIMS system for English news reading learning.

Table 14. The paired sample statistics of the self-assessing English news reading abilities of learners before and after learning (N = 15)

	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Before	6.67	15.00	1.14	0.30
After	7.70	15.00	0.92	0.24

Table 15. The paired sample t-test results of the self-assessing English news reading abilities of learners before and after learning

	Paired Differences					**t**	**df**	**Sig. (2-tailed)**
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
				Lower	**Upper**			
Before - After	-1.03	0.64	0.17	-1.39	-0.68	-6.25	14.00	.000

Research Discussion

In this section, how to apply the proposed scheme to the reading learning of any languages is first discussed. Additionally, the characteristics of the proposed mobile-based personalized reading learning scheme are critically examined and compared with several past research findings of computer-assisted reading learning. Moreover, the ownership issue is addressed to emphasize that it is one of five critical success features while performing mobile learning. Finally, mobile learning associated with learning context is also discussed herein.

How to Apply the Proposed Scheme to the Reading Learning of any Second Languages

In this study, the proposed PIMS system can recommend appropriate English news articles to individual learners according to their reading abilities estimated by the proposed fuzzy Item Response Theory. The experimental results demonstrated that the personalized reading learning of English news articles with enhancing unfamiliar vocabularies facilitates learners' reading abilities. Actually, the recommended learning article by the proposed PIMS system could be any kinds of language article with a corresponding difficulty parameter. Certainly, how to precisely evaluate the difficulty of a reading article to any considered second languages is the most critical issue for the proposed scheme of aiding reading learning. Thus, the proposed learning mechanism can be adopted as an effective strategy for the reading learning of any second languages except for English reading learning. Moreover, the proposed PIMS system implemented on mobile devices is beneficial to reading learning anytime, anywhere, thus enabling learners utilizing their spare time for reading learning.

Comparison of the Research Results with the Past Researches in L2 Reading and Vocabulary Acquisition

In this study, the experimental results indicated that English news reading learning accompanied with unfamiliar or new vocabulary learning provides benefit to promote reading comprehension and learners' reading abilities. The results confirm those of Huckin et al. (1993) and Alderson (1984), who claimed that vocabulary and vocabulary knowledge is helpful to promote reading comprehension as well as vocabulary is the main factor affecting reading performance in the second language. Moreover, up to 86.7% of learners who participated in the experiment agreed that English news reading learning with assistance of the corresponding Chinese translation provides benefits in terms of English news reading learning for Chinese students. Unlike the subject on "first-language interference" claimed by some scholars (Yorio, 1971; Cook, 1992; Krashen, 1981), this result of the study tends to support that accessing L1 is an assisted learning strategy to help L2 learners comprehend an L2 text. Furthermore, the promotion

of learners' reading learning performances in the study also confirms that the proposed personalized reading learning strategy based on individual reading abilities indeed helps learners to speed up reading performance and to reduce reading cognitive overload during the learning process. The result verifies that correct reading strategies emphasized by Alderson (1984) enable learners' successes in reading foreign language. Finally, the proposed PIMS aids learners to conduct ubiquitous language learning at any time from any place by mobile devices. This mechanism is very convenient to utilize learner's spare time for language learning because common advice from many English teachers on the best way for learning English is "little and often" (Buda, 1984).

Ownership of Mobile Learning

Naismith and Corlett (2006) surveyed many successful mobile learning projects in the proceedings of the mLearn conferences from 2002-2005, and identified five critical success features. One of five crucial factors mentioned in the study is ownership. From the point of view, learners will become more motivational, more active in communication and learn much better when they either own the novel learning tool or treat it as if they own it (Luckin *et al.*, 2004; Attewell & Webster, 2005; Facer *et al.*, 2005). In this study, each learner was distributed a PDA for English reading learning during five weeks. Before performing the experiment, all learners were told that they could use PDA whatever they wanted beyond English learning purposes. It means that learners can install any other software, be free to customize their PDAs, or even use it subversively, not just using PIMS system for English learning. According to our observations from the experiment, we found that most learners just followed our instructions and guidelines to use PIMS system everyday, not using the other features of PDA. However, if these 15 learners who treated PDA more as their own stuffs, then they would get great achievements in the activity of mobile English reading learning. Except the ownership of mobile equipment, the ownership of English learning is also a critical issue for learners to learn English well. In the study, all participants were volunteers and were asked to use PISM system in their school lives, not related to any English courses that they were majoring in. Nearly at the end of experiment, the learning activation in mobile English learning activity was gradually descending, because the date of school exam was approaching and they were being busy in preparing their midterm exams. We found that learners viewed mobile English learning as an extra work, not took it as their own English learning. Thus, how to support learners to use assisted learning tools and enhance their learning ownership in mobile learning, especially in English learning, is an essential issue. Although the results of questionnaire show that learners felt the PIMS system can promote their learning motivations and interests, our future efforts should focus on how to make learners view learning English as their own.

Pedagogy and Context of English Learning

In this study, the experiment was not conducted in a classroom environment, and all learners learnt English by the PIMS system as informal learning in their daily lives. Novel assisted tools that enable learners to perform new activities may change the way learners perceive and practice old activities, and may give rise to additional, unpredicted patterns of learning (Sharples *et al.*, 2007). Therefore, which mobile learning pedagogy is more benefit for English reading learning, what role a teacher should play for and how the interaction should be conducted in a classroom learning need to be further investigated. Additionally, the context of English learning is also important. In our experiment, one of 15 participators indicated that she preferred to use the PIMS system and learnt English in the school library or in the school restaurant, but the reading materials provided by the system were too serious, and not fit with her learning context. She hoped to read articles more related to her learning environment. However, the PIMS system provides great mobility for learners to learn English, but more efforts should consider how to appropriately recommend English reading materials to learners according to learners' learning contexts and support learners to construct knowledge from learning context.

Conclusion

This study proposes a personalized intelligent mobile learning system (PIMS) to promote the reading ability of English news for individual learners based on the proposed fuzzy Item Response Theory, which can estimate the reading abilities of individual learners and recommend appropriate English news articles to individual learners according to learners' simple feedback responses and difficulty parameters of the learned English news articles. Compared to the original Item Response Theory, the FIRT is superior to IRT because it can process non-crisp

response to correctly estimate learner's ability via the revised estimating function of learner's ability. Moreover, difficulty parameters of English news articles can also be appropriately determined by the proposed measuring scheme of difficulty parameter for non-native English speakers who treat English as second language. To enhance vocabulary learning while reading English news articles, the unknown or unfamiliar vocabularies of individual learners can also be automatically discovered and retrieved from the reading English news articles by the PIMS system according to the English vocabulary abilities of individual learners. Experimental results confirmed that recommending appropriate learning articles to individual learners provide benefits in terms of reducing learner cognitive overload during learning processes, thus promoting learning effects and interests. Meanwhile, the experimental results also indicated that English news reading learning accompanied with unfamiliar or new vocabulary learning provides benefit to promote reading comprehension and learners' reading abilities. In addition, the study tends to support that accessing L1 is an assisted learning strategy to help L2 learners comprehend an L2 text. More significantly, the proposed PIMS system enables a seamless ubiquitous learning environment for English learning at any time from any place by mobile devices.

Although the proposed PIMS provides benefits in terms of the promotion of English reading learning, there are several issues which are valuable to be further investigated. First of all, except news contents, providing diversified learning contents related to daily-life issues could further promote learning interests of learners while using the PIMS for reading learning. Secondly, adding the reading function accompanying with news announcer pronunciation may be helpful to simultaneously promote learner reading performance as well as listening comprehension. Additionally, the self-assessing feedback responses of reading comprehension of the learned news article replaced by reading test is another considered issue because it can effectively promote the accuracy of evaluating learners' reading abilities. Moreover, adding dictionary function for supporting vocabulary learning while reading learning has been considered as our future work according to the feedback responses of participants. More importantly, how to enhance learners' ownership while using PIMS for English reading learning should be viewed as an essential issue. Finally, developing a personalized context-aware ubiquitous English reading learning system, which can recommend appropriate reading learning contents associated with context-awareness information of individual learners, is also our future research issue.

Acknowledgement

The authors would like to thank the National Science Council of the Republic of China for financially supporting this research under Contract No. NSC 96-2520-S-004-001.

References

Alderson, J., & Urquhart, A. (1984). *Reading in a Foreign Language*, London: Longman.

Attewell, J., & Webster, T. (2005). Engaging and Supporting Mobile Learners. *Mobile learning anytime everywhere: A book of papers from mLearn 2004,* London: LSDA, 15-19.

Baker, F. (1992). *Item Response Theory: Parameter Estimation Techniques*, New York: Marcel Dekker.

Brusilovsky, P. (1999). Adaptive and Intelligent Technologies for Web-based Education. In C. Rollinger and C. Peylo (Eds.), *Künstliche Intelligenz, 4*, 19-25.

Buda, J. (1984). *Improving Your Reading Ability*, retrieved May 5, 2008 from http://www.f.waseda.jp/buda/texts/reading.html.

Cabrera, J. S., Frutos, H. M., Adrian, G. S., Avouris, N., Dimitriadis,Y., Fiotakis, G., & Liveri, K. D. (2005). Mystery in the Museum: Collaborative Learning Activities Using Handheld Devices. *Paper presented at the 7th International Conference on Human Computer Interaction with Mobile Devices & Services, September 19-22, 2005*, Salzburg, Austria.

Carrell, P. (1991). Second Language Reading: Reading Ability or Language Proficiency? *Applied Linguistics*, *12*, 159–179.

Chang, C. Y., Sheu, J.-P., & Chen, T.-K. (2003). Concept and Design of Ad Hoc and Mobile Classrooms. *Journal of Computer Assisted Learning, 19* (3), 336-346.

Chen, C. M., & Chung, C. J. (2006). Personalized Intelligent English Vocabulary Learning System Based on Item Response Theory and Learning Memory Cycle. *Paper presented at the IEEE International Conference on Systems, Man, and Cybernetics*, October 8-11, 2006, Taipei, Taiwan.

Chen, C. M., Hsieh, Y. L., & Hsu, S. H. (2007). Mining Learner Profile Based on Association Rule for Web-based Learning Diagnosis. *Expert Systems with Applications, 33* (1), 6-22.

Chen, C. M., Lee, H. M., & Chen, Y. H. (2005). Personalized E-Learning System Using Item Response Theory. *Computers & Education, 44* (3), 237-255.

Chen, C. M., Liu, C. Y., & Chang, M.-H. (2006). Personalized Curriculum Sequencing Using Modified Item Response Theory for Web-based Instruction. *Expert Systems with Applications, 30* (2), 378-396.

Chinnery, G. M. (2006). Emerging Technologies Going to the MALL: Mobile Assisted Language Learning. *Language Learning & Technology, 10* (1), 9-16.

Coady, J. (1979). A Psycholinguistic Model of the ESL Reader. In R. Mackay, B. Barkman & R. R. Jordan (Eds.), *Reading in a Second Language* (pp. 5-12), Rowley, MA: Newbury House.

Coady, J. (1997). L2 Vocabulary Acquisition through Extensive Reading. In J. Coady & T. Huckin (Eds.), *Second Language Acquisition* (pp. 225-237). New York: Cambridge University Press.

Cohen, A. D. (1995). In Which Language Do/Should Multilinguals Think? *Language, Culture, and Curriculum*, *8*, 99-113.

Collins, T. G. (2005). English Class on the Air: Mobile Language Learning with Cell Phones. *Paper presented at the Fifth IEEE International Conference on Advanced Learning Technologies*, July 5-8, 2005, Kaohsiung, Taiwan.

Cook, V. J. (1992). Evidence for Multicompetence. *Language Learning*, *42*, 557-591.

Cui, Y., & Bull, S. (2005). Context and Learner Modelling for the Mobile Foreign Language Learner. *System, 33* (2), 353-367.

Facer, K., Faux, F., & McFarlane, A. (2005). Challenges and Opportunities: Making Mobile Learning a Reality in Schools, retrieved May 30, 2008, from http://www.mlearn.org.za/CD/papers/Facer%20-%20Faux%20-%20McFarlane.pdf.

Flesch, R. (1948). A New Readability Yardstick. *Journal of Applied Psychology, 32* (3), 221-233.

Holzinger A., Nischelwitzer A., & Meisenberger M. (2005). Mobile Phones as a Challenge for M-learning: Examples for Mobile Interactive Learning Objects (MILOs). *Paper presented at the 3rd International Conference on Pervasive Computing and Communications*, March 8-12, 2005, Hawaii, USA.

Huckin, T., Haynes, M., & Coady, J. (1993). *Second Language Reading and Vocabulary Learning*, Norwood, NJ: Ablex.

Hwang, K., & Nation, P. (1989). Reducing the Vocabulary Load and Encouraging Vocabulary Learning through Reading Newspapers. *Reading a Foreign Language, 6,* 323-335.

Jolly, D. (1978). The Establishment of Self-access Scheme for Intensive Reading. *Paper Presented at the Goethe Institute, British Council Colloquium on Reading*, Paris.

Kern, R. G. (1994). The Role of Mental Translation in Second Language Reading. *Studies in Second Language Acquisition*, *16*, 441-461.

Kiernan, P. J., & Aizawa K. (2004). Cell Phones in Task based Learning-Are Cell Phones Useful Language Learning Tools? *ReCALL, 16* (1), 71-84.

Klare, G. R. (2000). The Measurement of Readability: Useful Information for Communicators. *ACM Journal of Computer Documentation, 24* (3), 107-121.

Krashen, S. D. (1981). *Second Language Acquisition and Second Language Learning*, Oxford, New York: Pergamon Press.

Lee, J., & Schallert, D. L. (1997). The Relative Contribution of L2 Language Proficiency and L1 Reading Ability to L2 Reading Performance: A Test of the Threshold Hypothesis in an EFL Context. *TESOL Quarterly*, *31*, 713-739.

Lee, M. G. (2001). Profiling Students' Adaptation Styles in Web-based Learning. *Computers & Education, 36*, 121-132.

Lin, B., & Hsieh, C. (2001). Web-based Teaching and Learner Control: a Research Review. *Computers & Education, 37*, 377-386.

Lin, C. T., & Lee, C. S. G. (1996). *Neural Fuzzy Systems: A Neuro-Fuzzy Synergism to Intelligent Systems*, Upper Saddle River, NJ: Prentice-Hall.

Luckin, R., Brewster, D., Pearce, D., Siddons-Corby, R. & du Boulay, B. (2004). SMILE: the creation of space for interaction through blended digital technology. In J. Attewell & C. Savill-Smith (Eds.), *Learning with mobile devices: research and development.* London: LSDA, 87-93.

Margaret, H. D. (2002). *Data Mining: Introductory and Advanced Topics*, Upper Saddle River, NJ: Prentice Hall.

Naismith, L., & Corlett, D. (2006). Reflections on Success: A Retrospective of the mLearn Conference Series 2002-2005. *Paper presented at the MLearn 2006 Conference*, 22-25 October 2006, Banff, Canada.

Nation, I. S. P. (1993). Vocabulary Size, Growth, and Use. In R. Schreuder & B. Weltens (Eds.), *The bilingual lexicon* (pp. 115-134), Philadelphia, PA: John Benjamins.

Papanikolaou, K. A., & Grigoriadou, M. (2002). Towards New Forms of Knowledge Communication: the Adaptive Dimension of a Web-based Learning Environment. *Computers & Education, 39*, 333-360.

Rogers, Y., Price, S., Randell, C., Stanton Fraser, D., W. M., & Fitzpatrick G. (2005). Ubi-learning Integrates Indoor and Outdoor Experiences. *Communications of the ACM, 48* (1), 55-59.

Rui, X. & Wunsch, D. II (2005). Survey of Clustering Algorithms. *IEEE Transactions on Neural Networks, 16* (3), 645-678.

Sharples, M., Milrad M., Arnedillo, S. I., & Vavoula, G. (2007). Mobile Learning: small devices, big issues. In Balacheff, N., Ludvigsen, S., de Jong, T., Lazonder, A., Barnes, S. & Montandon, L. (Eds.), *Technology Enhanced Learning: Principles and Products*, Berlin: Springer.

Shih, Y. E. (2005). Language in Action: Applying Mobile Classroom in Foreign Language Learning. *Paper presented at the Fifth IEEE International Conference on Advanced Learning Technologies*, July 5-8, 2005, Kaohsiung, Taiwan.

Tang, T. Y., & Mccalla, G. (2003). Smart Recommendation for Evolving E-Learning System. *Paper presented at the 11th International Conference on Artificial Intelligence in Education, Workshop on Technologies for Electronic Documents for Supporting Learning*, July 20-24, 2003, Sydney, Australia.

Ting, Y. L. (2005). Mobile Learning: Current Trend and Future Challenges. *Paper presented at the Fifth IEEE International Conference on Advanced Learning Technologies*, July 5-8, 2005, Kaohsiung, Taiwan.

Tummala, H., & Jones, J. (2005). Developing Spatially-aware Content Management Systems for Dynamic, Location-specific Information in Mobile Environments. *Paper presented at the 3rd ACM International Workshop on Wireless Mobile Applications and Services on WLAN Hotspots*, September 2, 2005, Cologne, Germany.

Upton, T. A., & Lee-Thompson, C. -L. (2001). The Role of the First Language in Second Language Reading. *Studies in Second Language Acquisition, 23,* 469-495.

Wang, Y. K. (2004). Context Awareness and Adaptation in Mobile Learning. *Paper presented at the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education*, March 23-25, 2004, Jhongli, Taiwan.

Wilkerson M., Griswold, W., & Simon, B. (2005). Ubiquitous Presenter: Increasing Student Access and Control in a Digital Lecturing Environment. *Paper presented at the 36th SIGCSE Technical Symposium on Computer Science Education*, February 23-27, 2005, St. Louis, Missouri, USA.

Yorio, C. A. (1971). Some Sources of Reading Problems for Foreign Language Learners. *Language Learning, 21*, 107-115.