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情境感知遊戲互動之合作式語言學習模式發展與學習成效評估研究(第3年)

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情境感知遊戲互動之合作式語言學習模式發展與學習成效評估研究

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摘要

為了提升國家競爭力，英語學習在非英語系國家普遍受到重視，因此發展有利於提升英語學習成效的電腦輔助學習模式顯得日益重要。因為字彙為組成英語句子的最根本要素，因此字彙學習對於提升英語學習成效就顯得相當關鍵且重要，因此過去已有不少致力於提升英語字彙學習成效的研究被提出。情境學習理論強調情境為語言學習歷程需要考量的要素，語言學習與情境學習結合可以有效提升語言學習成效。換句話說，有意義的語言學習必須與社會、文化及生活情境相互結合。近年來隨著情境感知技術的快速發展，發展能夠支援學習者進行不受時空限制的情境感知行動語言學習系統，成為一種提升英語學習成效的可能創新學習模式。因此，本研究在校園環境中提出一個個人化情境感知無所不在英語字彙學習系統，能夠根據學習者位置、學習時間、個人字彙能力及空閒時間，適性化的提供適合於個別學習者單字學習數量、單字程度及學習情境的英語字彙進行學習。實驗顯示本研究所提出之無線網路定位方法可以達到 92%的正確率，已經足以支援情境感知英語字彙學習。再則，本研究所提出之個人化情境感知無所不在英語字彙學習系統已經實作於個人數位助理 PDA 上，可以在校園環境提供情境感知英語字彙學習服務。實驗結果顯示，具有情境感知支援之個人化英語字彙學習系統的英語字彙學習成效優於不具情境感知支援之個人化英語字彙學習系統。

關鍵字：情境感知無所不在學習、無線網路定位、個人化學習、英語學習

Abstract

Since learning English is extremely popular in non-native English speaking countries, developing modern assisted-learning schemes that facilitate effective English learning is critical issue in English-language education. Vocabulary learning is vital within English learning because vocabulary comprises the basic building blocks of English sentences. Therefore, numerous studies have attempted to increase the efficiency and performance of learning English vocabulary. "The situational learning approach" proposed that "context" is an important consideration in the language learning process and can enhance learner learning interest and efficiency. Restated, meaningful vocabulary learning occurs only when the learning process is integrated with social, cultural and life contexts. With the rapid development of context-awareness techniques, the development of context-aware mobile learning systems, which can support learners in learning without constraints of time or place via mobile devices and associate learning activities with real learning environment, enables the conduct of a novel context-aware ubiquitous learning mode to enhance English vocabulary learning. Accordingly, this study proposes a personalized context-aware ubiquitous English vocabulary learning system based on learner location as detected by wireless positioning

techniques, learning time, individual English vocabulary abilities, and leisure time, enabling learners to adapt their learning content to effectively support English vocabulary learning in a school environment. Experimental results indicated that the accuracy of the employed wireless positioning scheme is over 92%, which is sufficient to help learners detect their location. Additionally, the personalized context-aware ubiquitous English vocabulary learning system has been successfully implemented on PDA devices in a school environment to support effective situational English vocabulary learning. Experimental analysis of learner learning performance indicates that the learning performance of learners who used personalized English vocabulary learning systems with context awareness was superior to learners who used personalized English vocabulary learning systems without context awareness.
Keywords: Context-aware ubiquitous learning, wireless positioning technique, personalized learning, English vocabulary learning

1. Introduction

The rapid development of wireless network technologies has enabled people to conveniently access the Internet from more diverse locations. WLAN offers an excellent solution for schools and companies wishing to establish Internet infrastructure. Additionally, the pervasiveness of handheld mobile devices, such as Tablet PC, PDA, and cell phone, has transformed learning modes from E-learning (electronic learning) to M-learning (mobile learning). Particularly, compared with traditional classroom learning, M-learning overcomes limitations of learning time and space. Recently, the concept of "context-aware ubiquitous learning" has been further proposed to emphasize the characteristics of learning the "right content" at the "right time" and "right place", and also to facilitate a seamless ubiquitous learning environment that supports learning without constraints of time or place (Ogata & Yano, 2004). The so-called "context-aware ubiquitous learning" (Rogers *et al.*, 2005; Tummala & Jones, 2005; Wang, 2004; Wilkerson *et al.*, 2005) thus requires the detection of learner context information and provides learning with different learning content via mobile devices in response to different learning contexts. Dey (2000) proposed four main types of contextual information, including identify, time, activity, and location, for building context-aware applications. To determine learner location, GPS (Global Positioning System) detects user location where the GPS receiver simultaneously senses a minimum of three satellites in outdoor environments by the triangulation method (Ahmed, 2006). Compared with GPS, WLAN can provide precise location information in both indoor and outdoor environments and has been widely set up in most public or school environments (Kupper, 2005). WLAN positioning is a more suitable method of enabling the development of "context-aware ubiquitous learning" that can provide learning content associated with learning contexts and assists learners in context-based learning in a campus environment.

Nevertheless, the rapid growth of the Internet has shortened the distance between people from different countries, making the world into a global village. English language abilities have become very important, and are now a basic skill for modern humans. Therefore, developing an effective learning tool for effective English learning has become an important issue in English-language education (Collins, 2005; Shih, 2005). EFL (English as a foreign language) learning requires the support of various learning tools to offer additional opportunities to learn English. Recently, various innovative learning methods have been proposed to support language learning activities, for example mobile English vocabulary learning by PDA (Chen & Chung, 2007), and some studies have proposed using cell phones to assist language learning (Kiernan & Aizawa, 2004; Collins, 2005).

Among all English-language skills, the English vocabulary competence is crucially important and is the foundation of language learning (Beck, McKeown, and Kucan, 2002; Bormuth, 1966; Davis, 1944, 1968). Huckin *et al.* (1993) indicated that reading ability and vocabulary knowledge are two key components of second language performance and moreover are mutually dependent, especially in academic settings. Additionally, Stahl & Fairbanks indicated that knowledge of word meanings is strongly related to reading comprehension skills (Stahl & Fairbanks, 1986). Moreover, Wilkins (1972) argued that "without grammar very little can be conveyed, and without vocabulary nothing can be conveyed." Recently, numerous studies have investigated English learning, and have particularly emphasized the importance of vocabulary learning (Lewis, 1993; McCarthy, 1984; Meara, 1980; DeCarrico, 2001). Excellent vocabulary abilities are beneficial in inferring meaning from English sentences (Harmon, 1998; Rupley, Logan & Nichols, 1999). The English language education field thus should pay more attention to developing innovative English vocabulary learning tools.

"The situational learning approach" (Hornby, 1950) proposed that "context" is an important factor in language learning, capable of enhancing learning interest and efficiency. Meaningful knowledge is constructed only when learning process integrates with cultural and life contexts. Assimilating knowledge in a real world environment shortens learning time and enhances learning efficiency. Moreover, learners who actively interact with the real word can apply this authentic and social knowledge to the everyday environment that surrounds them. Pestalozzi, an 18th Century philosopher, advocated the principle of Anschauung - direct concrete observation (Silber, K., 1965). Pestaloozi emphasized sensory experiences and encouraged the entry of natural science and geography. He frequently took children to explore the surrounding countryside, and especially to observe the local natural environment and topography. The children would examine the minerals, plants, and animals they encountered in the real environment, and then developed ideas based on their sensory impressions. Thus, exploring the real world and sourrding contexts benefits language learning. Miller and Gildea (1987) also indicated that learning vocabulary is an everyday practice, and using a sample of learners with an average age of 17 years old, they demonstrated that learners learn vocabulary at a rate of about 13 words per day. If vocabulary learning is meaningful to learners, they will naturally understanding the meaning and usage of the words learned. Generally, learning English vocabulary from abstract definitions in the dictionary is slow and less successful. More importantly, dictionary based learning leads to problems when using language in real world situations (Brow, Collins & Dugid, 1989).

Based on the situational learning approach and contextual information in the context-aware computational method proposed by Dey (2000), a "personalized context-aware ubiquitous English vocabulary learning system" based on considering four types of context-aware information, including learner location, current learning time, learner vocabulary ability and leisure time available to the learner is proposed to improve the English vocabulary learning of individual learners in this study. The proposed system uses existing WLAN infrastructure to gather AP signal strength information and detect location based on the employed back-propagation neural networks. Additionally, Item Response Theory (Baker and Frank, 1992; Hambleton *et al.*, 1985; Hambleton *et al.*, 1991; Hulin *et al.*, 1983) and the fuzzy inference mechanism (Lin & George Lee, 1996) were respectively employed to evaluate leaner vocabulary ability and the amount of learning vocabularies based on immediate test responses and leisure time of individual learners during learning processes. Experimental results demonstrate that utilizing context-awareness techniques associated with learning environment and content to memorize English vocabulary via mobile devices can reliably enhance English vocabulary ability. The effectiveness of this technique stems from the fact that context-aware ubiquitous learning facilitates learning activities by providing the "right content" at the "right time" and "right place", and is a convenient method for seamless ubiquitous English learning without constraints of time or place by mobile devices.

2. System Design

This section describes the proposed system architecture, positioning methodology and vocabulary recommendation mechanism. The functionalities of the proposed system, experimental environment, employed back-propagation neural networks, location estimation scheme are explained in Section 2.1, and the proposed positioning approach is detailed in Section 2.2. Finally, the recommendation mechanism for determining suitable vocabularies for individual learner based on context-aware is described in Section 2.3.

2.1 System Architecture

In this study, the "personalized context-aware ubiquitous English vocabulary learning system" is proposed, and it depends on learner location, learning time, leisure time and personal learning characteristics in terms of vocabulary ability to provide adaptive English vocabulary learning. The proposed system aims to enhance learner impressions and interest in relation to learning English vocabulary, and also to boost the performance of English vocabulary learning based on the situational learning approach supported by WLAN positioning techniques. Figure 1 illustrates the system architecture.

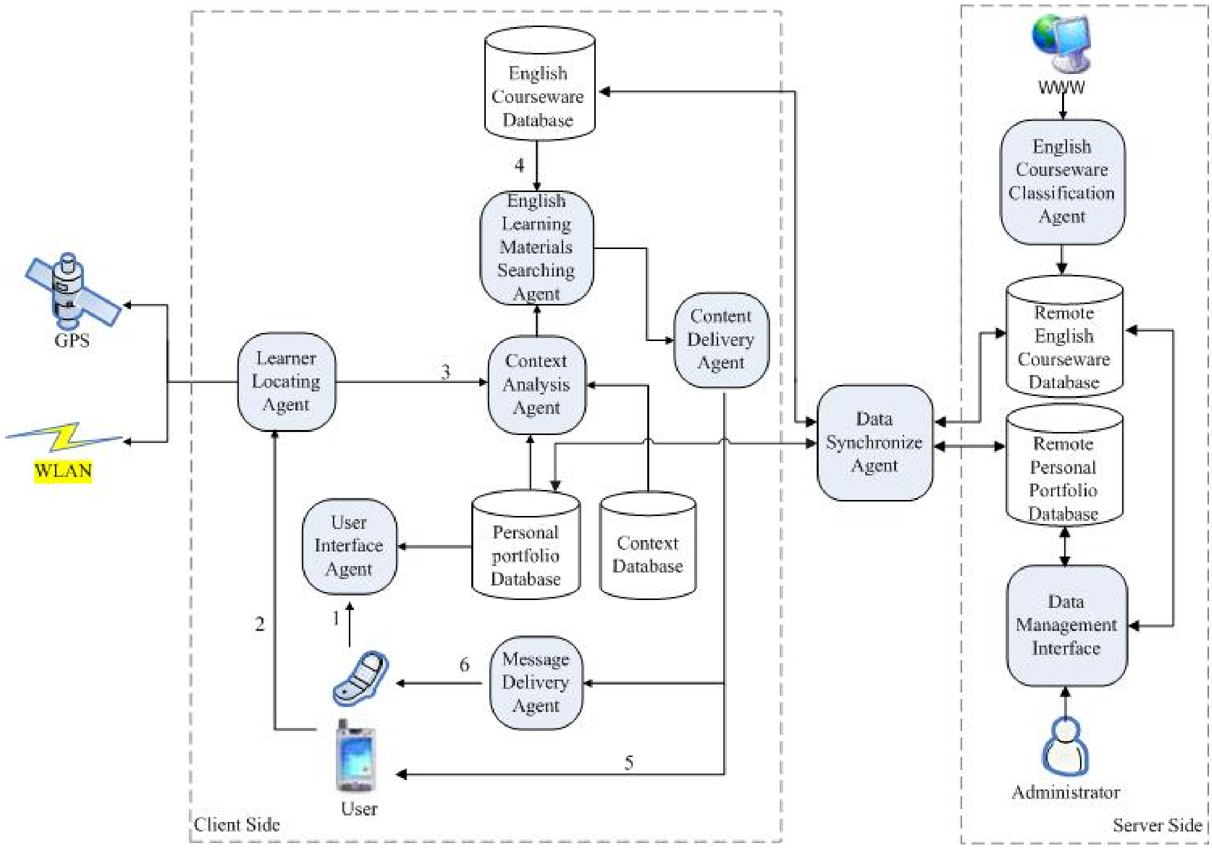


Figure 1. The system architecture of personalized context-aware ubiquitous English vocabulary learning system

2.1.1 System components

The proposed learning system is composed of the client side, data synchronized agent, and server side. The left part of Fig. 1 presents the system architecture of the client side. The client side, which comprises six intelligent agents and three databases, attempts to recommend new words to individual learners based on the proposed context-aware scheme for personalized English vocabulary learning. The right part of Fig. 1 shows the server side system architecture. The server side, which contains two databases, one data management interface, and one English courseware classification agent, is responsible for collecting English vocabulary from web sites that contain required English course materials and providing a friendly user interface for managing vocabulary by an administrator (i.e. an instructor). To support off-line learning, the data synchronized agent is responsible for maintaining data consistency between the client and server databases following the wireless network connecting. The functionality of each intelligent agent within the system is detailed below:

(1) The Client Side

(a) The learner locating agent

The agent attempts to detect the learner's location and can assist to choose different vocabularies depending on individual learner location. This study employed the WLAN positioning techniques in a schoolyard environment to sense learner location.

(b) The user interface agent

Learner can log into the learning process and decide to learn or review English vocabulary through the user interface agent. The user interface agent can also display individual learner learning states to improve understanding of individual vocabulary ability. This agent is also responsible for interacting with the user account database to confirm learner identity.

(c) The context analysis agent

Based on learner's location, this agent cooperates with both the personal portfolio and context databases to determine the learning parameters associated with the context.

(d) English learning materials searching agent

Suitable English learning materials that are related to the context of the sensing learner are discovered from the English courseware database based on the analytical results obtained by the context analysis agent.

(e) The content delivery agent

This agent organizes the English materials discovered by the English learning material searching agent into the right style of learning content that fits the learner's mobile device, then transmits these learning materials to the learner who is learning English vocabulary via PDA or cell phone.

(f) The message delivery agent

Except learning by personal digital assistant (PDA), if a learner learns English vocabulary through cell phone, the system will send learning content that match the learner ability and context in the form of short message to the learner; otherwise, the learning content will be sent to the PDA.

(g) The English courseware database

The English courseware database comprises English materials to support English vocabulary learning.

(h) The personal portfolio database

The personal portfolio database contains personal information, including learning statuses, and the English vocabulary abilities of individual learners.

(i) The context database

The context database contains the corresponding contextual information for each piece of English vocabulary as well as the location of the campus where the learning takes place, and this information is used to support the analysis of the context analysis agent.

(2) The Server Side

(a) The English courseware classification agent

Through information retrieval techniques, this agent automatically retrieves courseware from the web site with needed English course materials. Then it stores and classifies the course materials according to courseware difficulties and context attributes by human assistance.

(b) The data management interface

An administrator can add, modify or delete learning content, and assess the leaning states of individual learners through the data management interface.

(c) The remote English courseware database

The English courseware database comprises English vocabulary materials from the vocabulary collection of the Taiwan GEPT (General English Proficiency Test). These English vocabulary materials consist of three different GEPT grading levels: elementary, intermediate, and high-intermediate. The gathered GEPT vocabulary were used for English vocabulary learning by tenth grade high school students in this study.

(d) The remote personal portfolio database

Personal information, including individual learner learning status and English abilities, is stored in the personal portfolio database and the administrator can monitor learner learning activities and provide assistance as appropriate. The remote personal portfolio database maintains data consistency with the databases on the client side using the synchronized agent.

(3) The data synchronized agent

To support off-line learning, the data synchronized agent oversees the task of maintaining data consistency between the client and server databases following the wireless network recovers on-line connection. In this study, the merger replication technique provided in Microsoft SQL server was employed to perform this task.

2.1.2 System operation procedure

Based on the system architecture, the details of the client side system operating procedure are described and summarized below:

Step 1 A learner logs in to the proposed English vocabulary learning system through the user interface. As the learner logs in to the system, the user interface agent checks the individual learner account stored in the user account database and also checks the leisure time available for English vocabulary learning. Meanwhile, the setting information is stored in the personal portfolio database.

Step 2 Following the learner logs in the system, the learner locating agent automatically senses the learner location by the proposed neural-network-based WLAN positioning techniques.

Step 3 and 4 Based on the location of the sensing learner, the context analysis agent retrieves the context information from the personal portfolio and context databases. Consequently, the English learning material searching agent discovers the proper English vocabulary materials that fit learner context according to the analytical results of the context analysis agent.

Step 5 The content delivery agent organizes the English learning materials discovered by the English learning material searching agent as the appropriate form of content and transmits them to the learner device.

Step 6 The message delivery agent transmits the learning contents in the form of a web page to the learner’s PDA or in the form of short message to the learner’s cell phone. The user then returns to **Step 2** to perform the next learning cycle or logs out, terminating the learning process.

2.2 WLAN Positioning Methodology

Detecting the location context is an important function in this study. After analyzing the advantages and disadvantages of several positioning techniques and considering the limitations of real world environments, this study employed the neural-network-based WLAN positioning technique to develop a positioning service based on the wireless network existing in a schoolyard because WLAN has been widely installed in most schoolyards to provide wireless Internet services. Compared with the RFID, infrared and ultrasound positioning techniques (Kupper, 2005), WLAN has the lowest positioning infrastructure costs. Furthermore, this study employed back-prorogation neural networks, a machine learning technique, to induce the mapping relationships of the collected signal strength information with learner location. Subsequently, the trained back-prorogation neural networks were used to predict learner positions in accordance with the positioning inducing knowledge. The following subsections first introduce the employed back-propagation neural networks and their applications. Finally, the procedures used to detect learner location are detailed.

2.2.1 The employed back-propagation neural networks

The back-propagation neural network is an artificial neuron computing system (Lin & George Lee, 1996). Much like the human brain, a neural network is composed of interconnected nodes and directed links with corresponding weight information. Among the proposed neural network learning models, back-propagation neural network is the most widely used in practice and it is well known for its high accuracy, good generalization ability and rapid recall process. This study used the back-propagation neural network model to classify signal strength features into corresponding locations. A back-propagation neural network is a supervised model and includes both learning and recall phases. In the learning phase, the model learns how to map the input data to the corresponding output data, and also determines the weights of the network connections. The induced weights are then used to compute the output newly arrived data for prediction purposes. A typical back-propagation neural network architecture consists of input, hidden and output layers. Each layer receives the output of the precedent layer as an input. Figure 2 illustrates the architecture of the neural network with a single hidden layer used in this study. The signal strength of each AP serves as the input feature of each neural node in the input layer, and the outputs represent the corresponding locations.

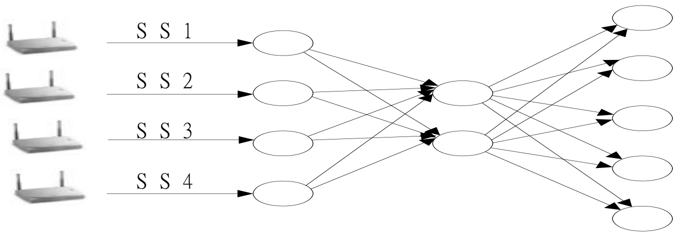


Figure 2. The learning architecture of the employed BP neural network with single hidden layer for WLAN positioning

2.2.2 Location detection

This study utilizes indoor WLAN to estimate learner location. By measuring the signal strengths emitted by each AP, the location is used to infer learner context. The location detection involves two stages, as described below:

- **The first stage (off-line phase)**

To establish the radio map database, plenty of signal strength samples were gathered to construct a neural network classifier model for inferring signal strengths into corresponding geographic locations. Each record represents the signal strength values emitted from *n* APs and their corresponding locations, and can be stored using the following format: *{SS_1, SS_2, SS_3, SS_4, … , SS_n, Location}*. During the data collection, some locations may have weak or even no signals because of long distances between the mobile side and the APs, or blocks of walls. Since the signal strength ranged from –30 dBm to –100 dBm, the signal strength value was assigned to –100 dBm for the location where no signal strength was detected.

- **The second stage (on-line phase)**

The back-propagation neural network model established during the first stage is implemented and installed on the learner mobile side (PDA). When a learner initiates the positioning service, the trained neural network model implemented in the learner locating agent immediately identifies the location of the learner according to the signal features detected by the learner's mobile device.

2.3 Recommending Context-Aware English Vocabulary and Testing Sheet

The system learning process comprises learning new English vocabulary and testing learners on their recently learned vocabulary. First, the context analysis agent is in charge of recommending context-based English vocabulary to individual learners based on four considered context information including learner vocabulary ability, learning location, current learning time, and free time available to the learner. A test sheet related to the learned vocabulary is then generated to assess learning performance and re-evaluate the English vocabulary ability of the learner. Figure 3 presents a detailed flowchart on the process of recommending context-aware English vocabulary. First, the proposed English vocabulary recommendation mechanism selects English vocabulary associated with learner location from the English courseware database for further consideration of whether this vocabulary is suited to learner English vocabulary ability and matches their free time availability characteristics. Next, the information function values of the selected vocabularies in the previous step estimated based on individual learner vocabulary ability were applied to identify appropriate English vocabularies for individual learner learning. Meanwhile, these selected vocabularies were also assessed in terms of their time characteristic scores based on learner learning time. A linear combination approach with an adjustable weight was applied to integrate the information function value with the time characteristics score to derive a final score for determining appropriate vocabularies for individual learner learning. In this study, all selected vocabularies associated with learner location were ranked according to final scores. Finally, the proposed system recommends vocabulary based on the ranking order of final scores. Moreover, the recommended amount of learning vocabularies is inferred based on individual leaner ability and leisure time. That is, if the estimated amount of learning vocabulary is K, then the vocabularies with top K high final scores are recommended to individual learners for vocabulary learning. The following subsections explain this vocabulary recommendation strategy in detail.

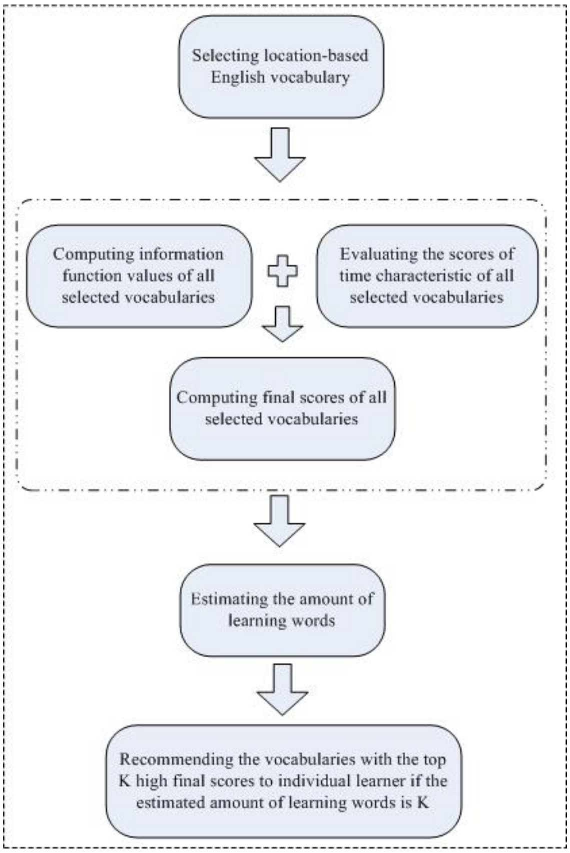


Figure 3. The proposed context-aware English vocabulary recommendation mechanism

2.3.1 Selecting location-based English vocabulary

Location information is the main factor in context-aware or context-based systems. According to the situational learning approach, this study first focused on recommending English vocabulary related to current learner location to individual learners. For instance, some words, such as exam, student, and assess, are appropriate to be learned if the learner performs the learning process in a classroom, while other words, such as baseball, jump, and athletic, were appropriate for learners in a sports ground environment. Therefore, the first step in vocabulary recommendation is to select English vocabulary based on learner location. Next, the selected English vocabularies associated with current learner location are ranked to determine appropriate vocabularies for individual learners based on a weighted linear combination of the information function values and time characteristics scores. The following subsection demonstrates how to decide appropriate vocabulary for individual learners based on their existing English vocabulary ability using the information function in Item Response Theory (IRT).

2.3.2 Evaluating English vocabulary ability and recommending English vocabulary based on information function

Item Response Theory (Baker and Frank, 1992; Hambleton *et al.*, 1985; Hambleton *et al.*, 1991; Hulin *et al.*, 1983) is a widely used theory in education measurement, typically applied in the field of Computerized Adaptive Testing (CAT) (Horward, 1990; Hsu and Sadock, 1985) to select the most suitable items for examinees based on individual abilities. The CAT efficiently reduces test time and number of testing items, and can precisely estimate examinee abilities. The concept of CAT is applied to replace conventional measurement instruments (which are typically fixed-length, fixed-content and paper-pencil tests) in several real-world applications such as the Test of English as a Foreign Language (TOEFL) (http://www.toefl.org), Graduate Record Examinations (GRE) (http://www.gre.org), and Graduate Management Admission Test (GMAT) (http://www.gmat.org). In this study, IRT was applied to assess learner vocabulary ability for the proposed novel personalized context-aware ubiquitous English vocabulary learning system for personalized learning services.

To estimate a learner's English vocabulary ability, the item characteristic function with a single difficulty parameter proposed in IRT (Baker and Frank, 1992; Hambleton and Swaminathan, 1985; Hulin *et al.*, 1983) is used to model each vocabulary word. The formula for the item characteristic function with a single difficulty parameter is

$$P_j(\theta) = \frac{e^{D(\theta - b_j)}}{1 + e^{D(\theta - b_j)}} \qquad j = 1,2,...,n \tag{1}$$

where $P_j(\theta)$ denotes the probability that learners can memorize and recognize the j^{th} vocabulary at a level below their ability level θ, b_j is the difficulty of the j^{th} vocabulary, n is the number of vocabularies and D is a constant 1.702.

In Eq. (1), the probability $P_j(\theta)$ is equal to 0.5 when a learner's vocabulary ability θ equals the difficulty parameter for the j^{th} vocabulary word. Clearly, a learner must have a higher vocabulary ability to achieve a probability of 0.5 for memorizing the j^{th} vocabulary word when the difficulty of the j^{th} vocabulary word is increased.

In IRT, two methods are widely used when assessing a learner's ability—maximum likelihood estimation (MLE) and Bayesian estimation schemes (Baker and Frank, 1992; Hambleton and Swaminathan, 1985; Hulin *et al.*, 1983). Although the MLE procedure is simple and easily implemented, it produces divergent estimations for a learner's vocabulary ability when a learner has completely correct or incorrect test responses for all learned vocabulary words (Baker and Frank, 1992). The MLE method frequently overestimates learner vocabulary ability when test responses are completely correct. Conversely, MLE typically underestimates learner vocabulary ability when test responses are completely incorrect. Compared with the MLE procedure, the Bayesian estimation method is more complex and less efficient, and can solve the divergent estimation problem in the MLE procedure. Hence, the Bayesian estimation procedure always converges for all possible learner responses (Baker and Frank, 1992). Consequently, the Bayesian estimation procedure is applied to estimate learner vocabulary learning ability in this study. Bock and Mislevy (Baker and Frank, 1992) derived the quadrature form to estimate learner ability as

$$\hat{\theta} = \frac{\sum_{k}^{q} \theta_k L(u_1, u_2, ..., u_n \mid \theta_k) A(\theta_k)}{\sum_{k}^{q} L(u_1, u_2, ..., u_n \mid \theta_k) A(\theta_k)} \tag{2}$$

where $\hat{\theta}$ denotes the learner's vocabulary 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. (2), the likelihood function $L(u_1, u_2, \cdots, u_n \mid \theta_k)$ can be further described as

$$L(u_1, u_2, \cdots, u_n \mid \theta_k) = \prod_{j=1}^{n} P_j(\theta_k)^{u_j} Q_j(\theta_k)^{1-u_j} \tag{3}$$

where $P_j(\theta_k) = \frac{e^{D(\theta_k - b_j)}}{1 + e^{D(\theta_k - b_j)}}$, $Q_j(\theta_k) = 1 - P_j(\theta_k)$, $P_j(\theta_k)$ denotes the probability that learners can memorize the j^{th} vocabulary at a level below their ability level θ_k, $Q_j(\theta_k)$ represents the probability that learners cannot memorize the j^{th} vocabulary at a level below their ability level θ_k, and u_j is the correct or incorrect testing response obtained from the vocabulary testing result to the j^{th} vocabulary, i.e. if the answer is correct then $u_j = 1$; otherwise, $u_j = 0$.

In the proposed system, learner vocabulary abilities are limited between –3 and +3. That is, learners with $\theta = -3$ have the poorest ability, those with $\theta = 0$ have moderate abilities, and those with $\theta = +3$ have the best abilities. This system estimates learner vocabulary ability based on learner test responses. If a learner memorizes the recommended vocabulary words and provides correct test responses, then a learner's vocabulary ability will be promoted based on the estimated formula for learner ability in Eq. (2); otherwise, learner vocabulary ability will be descended.

Two approaches in IRT are commonly used to evaluate appropriate vocabulary words to individual learners—the information function strategy and Bayesian strategy (Baker and Frank, 1992; Hambleton and Swaminathan, 1985; Hulin *et al*., 1983). The information function strategy assumes that each vocabulary word with its corresponding difficulty parameter exhibits different information to a learner's learning. Vocabulary with a high information value is more suitable to be recommended to learners. Since the Bayesian strategy is more complex than the information function approach, the information function method is applied to estimate appropriate vocabularies for individual learners. The information function is defined as

$$I_j(\theta) = \frac{(1.7)^2}{\left[e^{1.7(\theta - b_j)}\right]\left[1 + e^{-1.7(\theta - b_j)}\right]^2} \quad (4)$$

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

2.3.3 Evaluating the score of time characteristic of vocabulary

After calculating the corresponding information function value of each vocabulary, the time characteristics of all selected location-based English vocabularies are also considered for use in calculating the time characteristic scores to further integrate with the information function values of vocabularies. The determination of time characteristic scores for vocabulary is designed to identify the English vocabulary associated with learning time when learners conduct learning activities. For example, certain vocabulary items, such as sleep, star, and dark, are suitable for learn at night since they are associated with nighttime. Furthermore, other words, such as cold and snow, should be presented to learners during winter since they are generally associated with this season. Thus, the context analysis agent can monitor learning time and evaluate vocabulary items within the system to seek matches with the current learning time, season or festival. When people discuss the beginning or end of specific times or reasons, different time or seasons have different time measures involving hour, week or month. For example, when discussing the afternoon, it can be said to refer to the period from1:00 pm to 5:30 pm, in which case the relevant unit of time measurement is hours. Moreover, when talking about spring, people may think of the time measure as month and define spring as running from February to April.

Furthermore, different festivals have different beginning and end ranges. For example, the Chinese New Year is a major celebration for Chinese people, with the celebratory atmosphere lasting two weeks or more. A comparable western festival is Christmas, which sees associated symbols such as Christmas trees, cards, wreaths and so on appear a month or more in advance of December 25th. Compared to Chinese New Year and Christmas, a celebration such as teacher's day is rather small scale and involves a much shorter time period.

Thus, based on above properties, fuzzy theory (Lin & George Lee, 1996) is suitable for describing the characteristics of different times. Therefore, the score of time characteristic is computed based on fuzzy inference in this study. Additionally, the vocabularies stored in the English courseware database were manually classified into different situational categories based on various time characteristics in advance. The fuzzy membership functions for each time characteristic are heuristically determined in this study. Figures 4(a) and (b) illustrate two examples of fuzzy membership functions used for the time characteristics of winter and Christmas.

Following the score of time characteristic of the j^{th} English vocabulary denoted as TC_j and the information function value denoted as I_j are decided, the final score S_j of the j^{th} English vocabulary can be measured using the following weighted linear combination function:

$$S_j = w \times I_{j(n)}(\theta) + (1-w) \times TC_j \tag{5}$$

where w is an adjustable weighting factor reflecting the relative importance of learner ability and the time characteristic, TC_j is the time characteristics score of the j^{th} English vocabulary, $I_{j(n)}(\theta)$ represents the normalized information value of the j^{th} vocabulary at a level below their ability level θ, and the range of $I_{j(n)}(\theta)$ is between 0 to 1.

After calculating the corresponding final score of vocabulary, vocabularies with higher final scores are delivered first to individual learners. The following section discusses the quantity of vocabulary that should be delivered to individual learners based on learner leisure time.

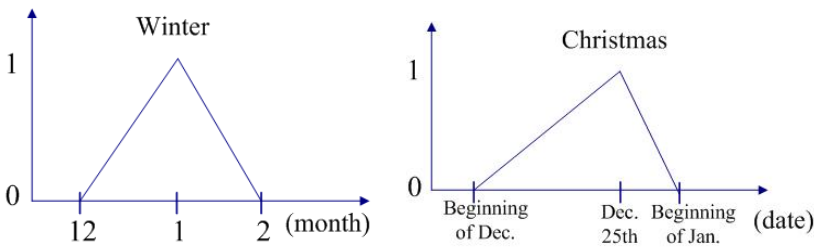


Figure 4. The defined fuzzy membership functions for winter and Christmas

2.3.4 Estimating the amount of learning words

Learners wishing to learn new vocabulary may differ in the free time they have available to do so. Learners may sometimes have very short periods of leisure time, such as when they are waiting for a few minutes for a friend to arrive. At other times learners may have much more time, such as after class. Hence, the quantity of recommended vocabulary to be learned should adapt to differences in the leisure time available to individual learners, to enable them to maximize their limited available time for learning. The context analysis agent decides the amount of learning vocabularies based on learner ability and available free time using pre-designed fuzzy rules. Before performing learning, the learner is asked to select a value between -1 and 1 to indicate the amount of free time they have available. Figure 5 shows the fuzzy membership functions determined for learner vocabulary ability and available leisure time. Table 1 lists nine fuzzy rules used to infer appropriate learning vocabulary based on learner ability and leisure time

Table 1. The designed fuzzy rules for inferring the number of learning vocabularies

Fuzzy rules					
No.	**If**				**Then**
1	Leisure.High	∩	Ability.High	→	Number.Mid
2	Leisure.High	∩	Ability.Mid	→	Number.High
3	Leisure.High	∩	Ability.Low	→	Number.High
4	Leisure.Mid	∩	Ability.High	→	Number.Mid
5	Leisure.Mid	∩	Ability.Low	→	Number.Mid
6	Leisure.Mid	∩	Ability.Low	→	Number.Mid
7	Leisure.Low	∩	Ability.High	→	Number.Low
8	Leisure.Low	∩	Ability.Mid	→	Number.Low
9	Leisure.Low	∩	Ability.Low	→	Number.Mid

Taking rules 1 and 2 as an example, if a learner has achieved a relatively high English vocabulary ability as a result of learning, the learning system will recommend more difficult English vocabularies. In contrast, learners with lower English vocabulary abilities will be given easier vocabulary to learn. Under the same leisure time, learners with high English vocabulary ability require more time to memorize more difficult vocabularies than do learners with moderate English vocabulary ability. Thus, in rules 1 and 2, learners with higher English vocabulary ability will be recommended less vocabulary than those with moderate English vocabulary ability to encourage them to completely memorize the recommended vocabulary during their leisure time.

Moreover, Figure 6 shows the defined fuzzy membership function for estimating the number of learning vocabularies. Besides, a defuzzification process was employed to infer learning vocabulary number based on the designed fuzzy rule base via fuzzy inference. In the fuzzy set theory, the center of gravity (COG) (Lin & George Lee, 1996), which is the most widely used defuzzification scheme, calculates the crisp values of learning vocabulary number from the most typical values and respective degrees of membership function. If the estimated number of learning vocabularies is *K*, the system will deliver the top *K* English vocabularies to the learner according to the ranking order of the final scores.

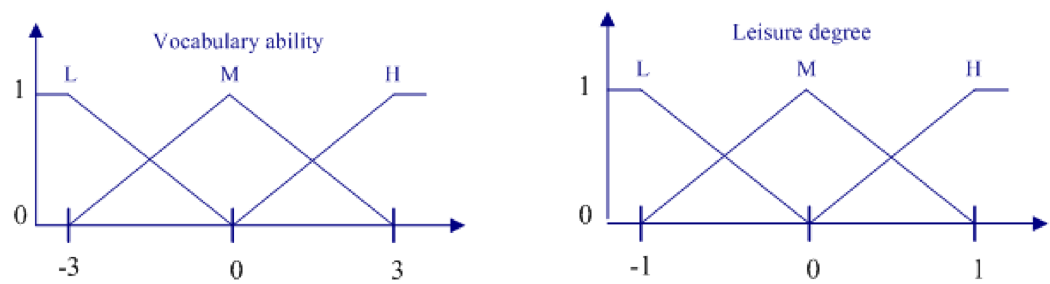


Figure 5. The determined fuzzy membership function for vocabulary ability and leisure time of learner

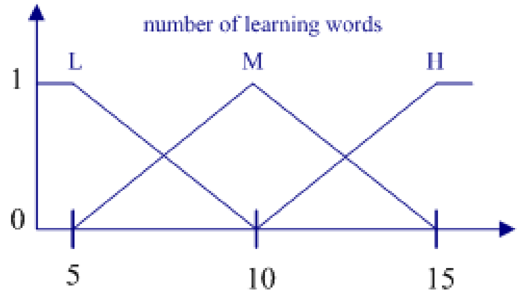


Figure 6. The defined fuzzy membership function for inferring the number of learning vocabularies

3. Experiments

Section 3.1 first describes the positioning experiment to verify whether the accuracy rate of WLAN positioning scheme satisfies the requirement supporting context-aware learning in the experimental campus environment. Section 3.2 demonstrates the implemented personalized context-aware ubiquitous English vocabulary learning system proposed in this study. Finally, section 3.3 evaluates the learning effectiveness of the proposed personalized context-aware ubiquitous English vocabulary learning system. In this work, a nonequivalent pre-test-post-test group based on the quasi-experimental design was designed to conduct learning activity and 36 tenth grade students in the Affiliated High School of National Chengchi University (http://www.ahs.nccu.edu.tw/) were invited to participate in this experiment during two weeks.

3.1 WLAN Positioning Experiment

To collect signal strength features for training the employed back-propagation neural network is the most important work affecting positioning learner location in the proposed English vocabulary system. Herein, the accuracy and the practicality of this approach were evaluated by the experiment in order to confirm whether this approach satisfies the actual requirement of the proposed system. The following subsections detail the experimental procedure and results.

3.1.1 Experimental environment

The experimental environment of wireless positioning was established on the fifth floor of the Wu-Shou Building in the National Hualien University of Education. The layout of this floor is shown as Fig. 7. It has dimensions of 80.5m by 11.3m and includes office, meeting room, and hallways. Four IEEE 802.11b WLAN access points were installed on this floor and users use PDA with the Pocket PC 2003 operating system as mobile device. This floor is divided into five areas based on the room spatial distribution: (A) office, (B) U-shaped hallway I, (C) meeting room, (D) U-shaped hallway Ⅱ, and (E) U-shaped hallway Ⅲ.

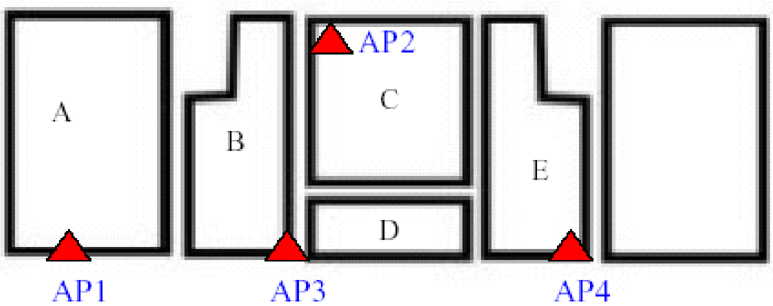


Figure 7. The layout of experimental environment in the Wu-Shou Building (the red triangles

signify the wireless Aps)

3.1.2 Filtering noisy training data

In this study, the fifth floor of Wu-Shou Building is divided into five areas and 200 records of signal strengths are sampled from each area. Hence, there are totally 1000 records of signal features collected and applied as training data for training the applied back-propagation neural networks. However, for some reasons such as multi-path, and refraction, the signal therefore generates irregular fluctuation and becomes as noisy data. Therefore, it is essential to apply noisy data filtering mechanism to eliminate noisy training data. Once the better training data is generated after filtering out noisy data, the learning effect of neural network can be obviously promoted.

The noisy data filtering mechanism proposed in this study is based on the concepts of mean and bias in the statistics analysis. The steps of filtering out training data are elaborated as follows:

Step 1. Computing the mean $\{M_1, M_2, M_3, M_4\}$ of all signal feature vectors $\{SS_1, SS_2, SS_3, SS_4\}$ in each area.

Step 2. Computing the bias of each data record against the mean according to the following formula and denoted as $\{K_1, K_2, K_3, K_4\}$:

$$K_i = \frac{SS_i - M_i}{M_i} \tag{6}$$

Step 3. Normalizing the bias $\{K_1, K_2, K_3, K_4\}$ of each data record into $\{F_1, F_2, F_3, F_4\}$ based on the following formula:

$$F_i = \frac{1}{K_i^{\,2} + 1} \tag{7}$$

To obtain qualified training data, the threshold of F_i is set to 0.85 in this study. The record that all values in vector $\{F_1, F_2, F_3, F_4\}$ are greater than or equal to 0.85 will then be preserved as training data, the others are filtered out.

3.1.3 Accuracy rate analysis of detecting learner location

To enhance learning performance for precisely detecting learner location, this study heuristically determines the number of hidden-layer neural nodes of the employed back-propagation neural networks. Furthermore, merely sensing signal strength features once from each AP may simply reflect noise and result in incorrect location decision. To reduce interference from signal fluctuation and improve the accuracy of position prediction, the signal strength features are measured more than once and supplied prior to the positioning estimation in this study. In the estimations, the area label with the largest number of appearances serves as the final positioning result. For example, a learner is located in area A, and the sampling parameter is set to 5. If the location decisions determined by the employed neural-network-based positioning scheme are 4 for area A and 1 for area B, respectively, then the final positioning result is judged to be area A. In contrast, if the location decisions determined by the employed neural-network-based positioning scheme are 2 for area A and 3 for area B, the final positioning result is judged to be area B.

To determine the appropriate number of sampling parameters for positioning estimation, ten measurement points are randomly selected from each area and three iterations are measured on each measurement point. The sampling parameter for the measurement ranges from 3 times to 10 times. The accuracy rate of location estimation in each area can be computed by the following formula:

$$LAR_{m,n} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} v(s_k)}{m \times n} \times 100\% \qquad (8)$$

where $LAR_{m,n}$ denotes the location accuracy rate with iteration of m measurements and the n measurement points randomly selected in some area, the notation i denotes the i^{th} iteration measurement in some area, j denotes the j^{th} measurement point randomly selected in some area, and the notation $v(s_k)$ denotes the voting result in one measurement point of some area assumed that the sampling parameter is set to k.

Moreover, $v(s_k)$ is further computed as follows:

$$v(s_k) = \begin{cases} 1, \text{if the voting location label of the } k^{th} \text{ sample is the same with the real location label} \\ 0, \text{others} \end{cases} \qquad (9)$$

Table 2 illustrates the tested positioning accuracy using different sampling parameters. The experimental results demonstrate that overall accuracy increases when the value of the sampling parameter increases from 3 to 8. The best location accuracy of 92.7% occurs when the sampling parameter is set to 8, and is enough to aid the location detection of learner. However, how to determine the optimal sampling parameter for WLAN positioning requires further investigation.

Table 2. The testing accuracy rate of WLAN positioning with different sampling parameters

Location / The used sampling parameter	A	B	C	D	E	Average accuracy rate (%)
3	90	73.3	70	83.3	73.3	78
4	96.7	96.7	73.3	90	73.3	86
5	96.7	90	66.7	76.7	76.7	81.3
6	90	96.7	56.7	90	86.7	84
7	100	86.7	86.7	96.7	90	92
8	96.7	100	86.7	93.3	86.7	92.7
9	100	83.3	66.7	90	83.3	84.7
10	100	93.3	86.7	93.3	76.7	90

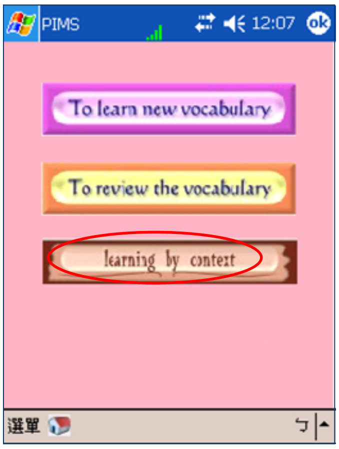
3.2 The Implemented System on PDA Supported by a Courseware Management Server

This section details the personalized context-aware ubiquitous learning system implemented by the platform of Microsoft Visual Studio .Net 2003. Currently, the client mobile learning system is implemented on the PDA with the operating system of Windows mobile 2003 and the database of Microsoft SQL Server CE edition 2.0. Moreover, the remote courseware management server is implemented on the Microsoft Windows 2000 Server with Microsoft SQL Server 2000 database.

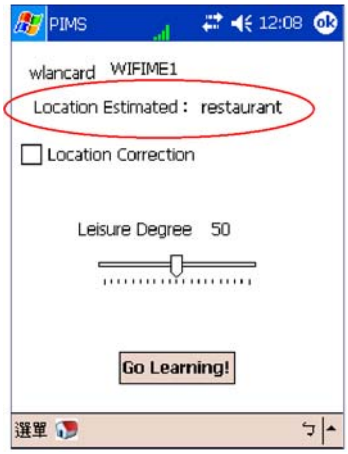
First, Fig. 8(a) shows the menu of vocabulary learning after a learner logs in the system by a legal account. If the learner would like to perform the context-aware learning mode, then he/she can click the button of "learning by context" and the learning locating agent will begin to sense the learner location. Figure 8(b) reveals the result of location detection and the system will remind learner to adjust the current leisure degree for inferring appropriate number of vocabularies for learning. Figure 8(c) shows the additional functionality for correcting location information. That is, learners can correct location by the interactive interface with prior building location information.

After the learner selects to continues the learning process, the context analysis agent and English learning material searching agent will find out suitable vocabularies to the learner according to the learner's ability, leisure degree, current location and current learning time. Figures 8(d) and 8(e) show the recommended English vocabulary and the number of learning vocabularies decided by the context analysis agent. Meanwhile, learners can click on the trumpet-shaped button to listen the pronunciation of the selected vocabulary for training listening ability. Suppose that different learners locate at the same place "restaurant", Figs. 8(d) and 8(e) display the system can recommend appropriate vocabulary to individual learners according to different learning time. In Fig. 8(d), the vocabularies with the characteristic of Christmas have higher priorities to be recommended to the learner because the learning time is close to Dec. 25th. However, Fig. 8(e) shows when the learning time is on Feb. 25th, the vocabularies characterized by Christmas are no longer ranked as the first priority vocabulary owing to approaching to the end of Christmas. After studying these recommended English vocabularies, the learner has to perform the corresponding vocabulary test to re-examine the individual vocabulary ability and the user interface agent will reveal the test results to the learner. Figures 8(f) and 8(g) show the contents of the test question and the test result.

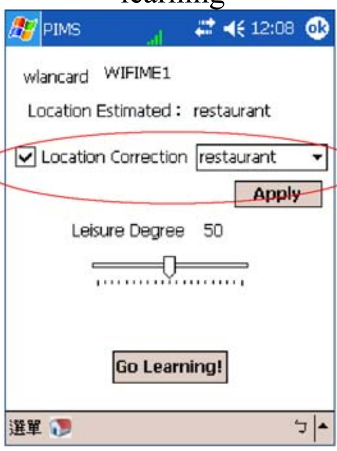
Additionally, the learning statuses of each learner will be sent to the courseware management server and stored in the personal portfolio database. The courseware management server provides a friendly user interface for teachers to inspect the learners' learning portfolios in order to further understand the learning performance of individual learners. Figure 9 shows the server side interface provided for teachers or administrators.



(a) The menu of context-aware ubiquitous learning



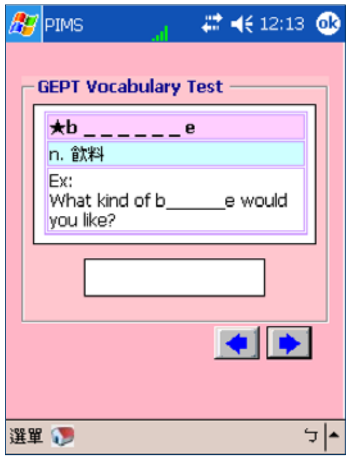
(b) The result of learner location estimation



(c) The functionality of location correction

(d) The learning content at restaurant on December 21

(e) The learning content at restaurant on February 25



(f) The corresponding test of the learned vocabulary

(g) The test result

Figure 8. The implemented personalized context-aware ubiquitous English vocabulary learning system

Figure 9. The courseware management server for managing English vocabulary and learner learning portfolios

3.3 Experimental Design and Analysis

3.3.1 Experimental design

To evaluate the learning performance of the proposed personalized context-aware English vocabulary learning system, 36 tenth grade students studying in the Affiliated High School of National Chengchi University were invited to participate in this experiment. The students were randomly assigned to either the experimental or control groups. Each group contained 18 students with the average age being around 16 years old. Each group contained 9 males and 9 females. A nonequivalent pre-test-post-test group based on a quasi-experimental design was employed to analyze the learning performance of the proposed system. Table 3 lists the experimental design of both the experimental and control groups.

Table 3. The experimental design for assessing learning performance

Group	PDA Operation Training	Pre-test	Learning process (2 weeks)	Post-test	Number of learners	Female	Male
Experimental group	✓	✓	Vocabulary learning with context aware service	✓	18	9	9
Control group	✓	✓	Vocabulary learning without context aware service	✓	18	9	9

Before performing the experiment, all participants received a 100 minute training course in operating PDA and using the proposed English vocabulary learning system with or without context-aware service. Figure 10 shows the learning situation of students who participated in the training course. In this experiment, the experimental group learned the recommended vocabulary with the support of the proposed context-aware service, while the control group learned the same vocabulary without such support. The vocabulary learning activity of two groups lasted two weeks. Both the learning modes performed the pretest and posttest for comparing the difference in learning performance before and after learning using PDA. To provide a context-aware service for English vocabulary learning in the experimental schoolyard, 12 campus locations in the Affiliated High School of National Chengchi University were chosen to provide a location-based context-aware service. Table 4 lists the selected locations for the context-aware service. The students of the experimental group were free to go to these places at anytime and the proposed system could recommend suitable English vocabulary related to learning environment to individual learners for English vocabulary learning. Figures 11(a) and 11(b) illustrate the learning scenario of the experimental group students that learned English vocabulary via the proposed personalized vocabulary learning system with context-aware service in the library and garden, respectively.

Figure 10. PDA operation training

Figure 11(a). Vocabulary learning in the library using proposed system

Figure 11(b). Vocabulary learning in the garden using proposed system

Figure 11. Vocabulary learning in various places using the proposed system

Table 4. The selected locations for English vocabulary learning in the schoolyard of the Affiliated High School of National Chengchi University

Military classroom	Clinic center	Garden
Computer classroom	Restaurant	Gym
Meeting room	Art classroom	Library
English classroom	Music classroom	Chemistry laboratory

To assess learning performance, two parallel versions of the testing sheet were constructed by an experienced English teacher at the Affiliated High School of National Chengchi University for both the pre-test and post-test, and were used respectively to measure student English vocabulary abilities before and after performing the learning process. Each testing sheet contained 20 multiple-choice items and 20 cloze questions selected equally from among three vocabulary levels of GEPT in Taiwan. Another 40 tenth grade students, excluding students in the experimental and control groups, were invited to participate in the tests before the experiment was conducted, and the test results were submitted for item analysis to measure whether the difficulties of both the pre-test and post-test sheets are identical. The analytical results show that the Kuder-Richardson reliability coefficients for both the pre-test and post-test sheets are 0.66 and 0.80, respectively, meaning both testing sheets have consistent reliability. Moreover, the Pearson Product-Moment correlation coefficient of both the test sheets is 0.70, and thus both testing sheets are confirmed to have identical levels of difficulty.

3.3.2 Experimental analysis

3.3.2.1 Learning performance analysis

Figure 12 displays the comparison result of the learning performance for both the pre-test and post-test. Table 5 shows the summarization of learning performance for both the participating groups. Figure 12 reveals the score differences of pre-test and post-test in the control group are closer than those in the experimental group. In addition, the percentages of learners with progress score in both the experimental and control groups are 94% and 67%, respectively. The results show that the scores of both the groups have progress, but the score progress of the experimental group is obviously superior to the control group.

In order to investigate whether there are significant differences in score progress between both the experimental and control groups, SPSS statistical software was used to analyze the result of pre-test and post-test. The SPSS analysis results of pre-test are presented in Tables 6(a) and 6(b). In this work, the Independent-samples T Test was employed to analyze the collected data of two participating groups. Before performing the PDA learning process for English vocabulary learning, the mean score of the experimental group on the pre-test is 10.39 and the standard deviation is 3.032. The mean score of the control group on the pre-test is 12.61 and the standard deviation is 5.315. The result of Independent Sample T Test (sig of $t = 0.135 > 0.05$) indicates that these two groups are not significantly different on the pre-test; therefore, the English vocabulary abilities of two groups can be viewed as identical before conducting the designed learning process.

Table 5. Summarization of learning performance for both participating groups

Group / Comparison Item	Experimental group	Control group
Number of learners	18	18
Number of learners with progress score	17(94%)	12(67%)
Number of learners with retrogression score	0(0%)	5(27%)
Number of learners with constant score	1(6%)	1(6%)

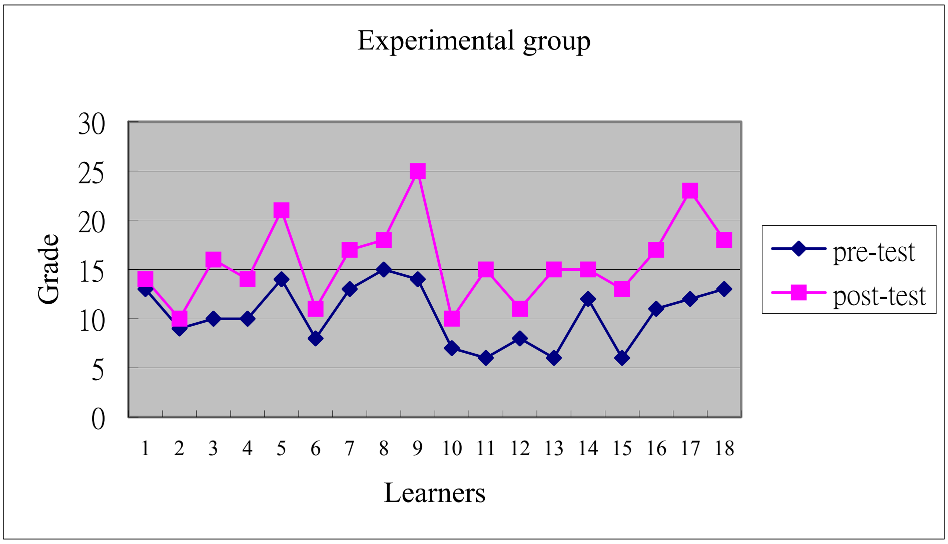
Table 6. The Independent Samples T Test of pre-test between two groups

(a) Group statistics

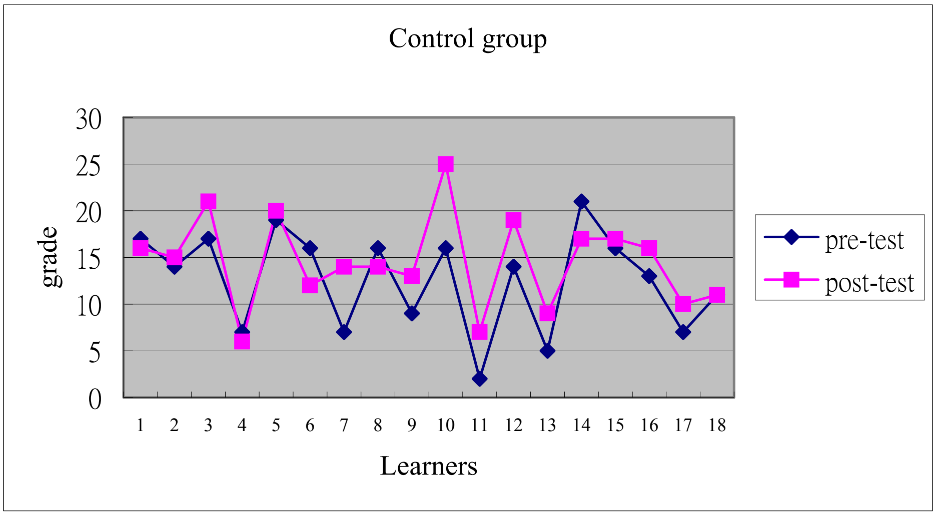
	class	N	Mean	Std. Deviation	Std. Error Mean
pretest	experimental group	18	10.39	3.032	.715
	control group	18	12.61	5.315	1.253

(b) Independent Sample T Test

	t-test for Equality of Means					
	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
pretest	27.004	.135	-2.222	1.442	-5.182	.737



(a) The students' learning performance in the experimental group



(b) The students' learning performance in the control group

Figure 12. The learning performance of two participating groups

Next, Tables 7(a) and 7(b) illustrate the Independent Samples T Test of post-test between two participating groups. The mean scores of the experimental and control groups on the post-test are 15.61 and 14.56, respectively. The T test result (t=0.684, sig of t=0.489 > 0.05) shows that two groups are not significantly different on the post-test. Thus, this study further compared the pre-test and post-test within each group using the Paired-Samples T Test.

Table 7. The Independent Samples T Test of post-test between two groups

(a) Group statistics

	class	N	Mean	Std. Deviation	Std. Error Mean
posttest	experimental group	18	15.61	4.258	1.004
	control group	18	14.56	4.973	1.172

(b) Independent Sample Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
posttest	.489	.489	.684	34	.499	1.056	1.543	-2.081	4.192

Tables 8(a) and 8(b) shows the result of Paired Samples T Test of the experimental group. In the experimental group, the difference of the mean scores between pre-test and post-test is –5.222 and the Paired-Samples T Test result reaches the significant level. In other words, after performing the proposed learning process, the promotion of learning performance in the experimental group is significant and the mean testing score increases 5.222 points. Tables 9(a) and 9(b) show the result of Paired Samples T Test of the control group. Similarly, the promotion of learners' learning performances is also significant and the mean testing score increases 1.94 points in the control group. Hence, these two groups made significantly progress whether using the personalized English vocabulary learning system with or without context-aware service for English vocabulary learning. However, the promotion of the testing score in the experimental group (5.222) is higher than that in the control group (1.944). Thus, this study logically inferred that the learning performance of learners who used personalized English vocabulary learning system with context-aware service is superior to the learners who used personalized English vocabulary learning system without context-aware service.

Table 8. The Paired Samples T Test of the experimental group

(a) Paired samples statistics

		Mean	N	Std. Deviation	Std. Error Mean
experimental group	pretest	10.39	18	3.032	.715
	posttest	15.61	18	4.258	1.004

(b) Paired Sample T Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
experimental group	pretest - posttest	-5.222	3.246	.765	-6.836	-3.608	-6.8	17	.000

Table 9. The Paired Samples T Test of the control group

(a) Paired samples statistics

		Mean	N	Std. Deviation	Std. Error Mean
control group	pretest	12.61	18	5.315	1.253
	posttest	14.56	18	4.973	1.172

(b) Paired Sample T Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
control group	pretest - posttest	-1.944	3.589	.846	-3.729	-.160	-2.299	17	.034

In order to further explain inter-group variation associated with pre-test (covariance) and adjust the treatment (group) effect, an analysis of covariance (ANCOVA) was used to analyze the collected pre-test and post-test data. The first step is to analyze the homogeneity of regression coefficients. Table 10 shows the analysis result (F=0.438, sig of F=0.513). The F test result does not reach the significant level, thus it means the regression slope of two groups is equivalent. This result confirms the assumption of homogeneity of coefficients, so this study further preceded the analysis of covariance.

Table 10. The analyze result of the homogeneity of regression coefficients

Dependent Variable: posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
group* pretest	4.882	1	4.882	.438	.513

Table 11 shows the ANOCA result (F=5.785, sig of F=0.022) after adjusting the dependent effect (group) with respect to the covariance (pre-test), and it reaches the significant level. This result indicates that the post-test of two groups has significantly different. Next, Table 12 displays the estimated score of post-test after removing the effect of covariance and this study found that the post-test score of the experimental group is higher than that of the control group. Thus, this study concluded that the learners who used the proposed vocabulary learning system with context-aware service had better learning performance than the learners who used the vocabulary learning system without context-aware service.

Table 11. The ANOCA result of two groups

Dependent Variable: posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
group	63.336	1	63.336	5.785	.022

Table 12. The estimated score of two groups after adjusting the dependent effect with respect to the covariance

Dependent Variable: posttest

class	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
control group	13.711[a]	.793	12.097	15.326
experimental group	16.455[a]	.793	14.841	18.069

a. Covariates appearing in the model are evaluated at the following values: pretest = 11.50.

3.3.2.2 Questionnaire analysis

To assess learner satisfaction degree for the proposed personalized context-aware English vocabulary learning system, a questionnaire involving 23 questions dealing with four areas was designed to measure whether the proposed English vocabulary learning system satisfies the requirements of most learners. The four question types contain personal information relating to learner learning by PDA, the convenience of system operation, the investigation of learner learning attitude towards using the proposed learning system, and the self assessment of learners' English vocabulary ability before and after using the proposed English vocabulary learning system. Table 13 summarizes the descriptions of question types. Eighteen learners in the experimental group were invited to complete this questionnaire after attending the two week learning activity.

Table 13. The descriptions of question types

Question Type	The number of questions	Description
Personal Information about Using PDA	3	To get the personal information about learners who attend the learning activity using the proposed system
System Operation	9	Questions related to the user interface and the content of learning materials
Learning Attitude	10	To investigate whether the system can enhance learners' learning motivation or interests and promote their learning achievements or not
Self Assessment	1	To ask learners for self-assessing their English vocabulary abilities before and after using the proposed learning system

Table 14 lists the results of satisfaction evaluation. To simplify the analytical results, the responses "strongly agree" and "agree" are merged into the single response of "approved", and the responses of "strongly disagree" and "disagree" are merged into the single response of "disapprove" The evaluation results indicate that the satisfaction degree of "approved" achieves 54.9% in terms of system operation and 56.1% with regard to learning attitude, as listed in Tables 14(b) and (c).

Table 14. 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 mobile phone with PDA?	3	15
	Do you use PDA first time?	13	5
	Have you ever used PDA for learning?	3	15

(b) The investigation results of the system operation

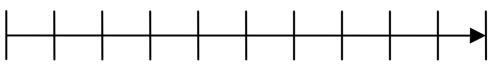
Question Type	Question	Satisfaction Degree (%)				
		strongly disagreed	disagreed	no opinion	Agreed	strongly agreed
System Operation	I think that the proposed context-aware ubiquitous English vocabulary learning system provides a friendly user interface.	0	0	27.8	44.4	27.8
	I am very clear about the learning procedure of the proposed context-aware ubiquitous English vocabulary learning system.	0	0	11.1	72.2	16.7
	I agree that applying location-based context-aware technique in the leaning is novel and it can assist my learning.	0	5.6	50	22.2	22.2
	I agree that the English vocabulary materials presented on the PDA are very clear.	0	17	38.9	44.4	0
	I agree that the vocabularies recommended by the system are highly relevant with my learning location and learning time.	0	5.6	61.1	27.8	5.56
	I think the proposed context-aware ubiquitous English vocabulary learning system is a useful learning tool to assist English vocabulary learning.	0	5.6	38.9	33.3	22.2
	I agree that learning English vocabulary by PDA is very convenient; because I can perform English learning at any time and place.	17	5.6	27.7	27.8	22.2
	The proposed context-aware ubiquitous English vocabulary learning system can effectively assist my learning.	5.6	5.6	44.4	38.9	5.56
	If there are similar English curriculums in the future, I am pleasure to use the proposed system to learn English once again.	5.6	11	22.2	38.9	22.2
	Average	9.4		35.7	54.9	

(c) The investigation results of the learning attitude

Question Type	Question	Satisfaction Degree (%)				
		strongly disagreed	disagreed	no opinion	Agreed	strongly agreed
Learning Attitude	The design learning materials on the proposed context-aware ubiquitous English vocabulary learning system can promote my learning interests.	0	11	44.4	33.3	11.1
	I often increase my learning time because learning by the proposed context-aware ubiquitous English vocabulary learning system promotes my learning interest.	5.6	5.6	38.9	38.9	11.1

	I think that using the proposed context-aware ubiquitous English vocabulary learning system can effectively promote my English vocabulary ability.	5.6	5.6	27.8	50	11.1
	I agree that using PDA to learn English vocabulary is a very interesting learning mode.	0	17	22.2	44.4	16.7
	The pronunciation of English vocabulary provided in the proposed system can help me deepen the memorized impression on vocabulary.	0	11	33.3	33.3	22.2
	I think that the integrating English vocabulary learning with the real learning environment is beneficial to my English vocabulary learning.	0	0	38.9	38.9	22.2
	After learning some vocabulary, a cloze test immediately given from the proposed system for the learned vocabulary is very helpful to vocabulary learning.	0	0	27.8	55.6	16.7
	The learning activity offered by the proposed context-aware ubiquitous English vocabulary learning system is more diversified than that of the traditional classroom English vocabulary learning.	0	11	38.9	33.3	16.7
	The proposed context-aware ubiquitous English vocabulary learning system satisfies user-oriented design.	5.6	11	33.3	44.4	5.56
	Compare to the traditional vocabulary instruction, learning English vocabulary based on the learning location and learning time is helpful to promote my linking and memorization on vocabulary.	0	11	33.3	38.9	16.7
	Average	10		33.8	56.1	

(d) The investigation results of the self-assessment

Question Type	Question	Vocabulary ability		
		Learner Number	**Before learning**	**After learning**
Self Assessment	This question aims at self-assessing your vocabulary ability. Please use the notations Δ and ○ to indicate your vocabulary abilities based on the following ability scale before and after using this mobile English vocabulary learning system, respectively.  0 1 2 3 4 5 6 7 8 9 10	1	2	4
		2	2	3
		3	3	5
		4	5	6
		5	4.5	6.5
		6	6.2	7.8
		7	5	6
		8	3.5	4
		9	5.5	5.5
		10	4	7
		11	5.5	6.5
		12	3	5
		13	4	4.5
		14	4	7
		15	2	5
		16	5	6
		17	5	5.5

		18	0.4	0.6
		Average	3.867	5.272

Moreover, in terms of self-inspection, 17 of 18 learners thought that their vocabulary abilities promoted after using the proposed system for English vocabulary learning, with just one learner not agreeing that their vocabulary abilities improved, and no learners believing that their vocabulary abilities had deteriorated. Table 14(d) lists the self-assessment results. The self-assessment results are then submitted to analyze whether learner English vocabulary abilities differ before and after performing learning activity. The analytical results are listed in Table 15 and reveal that learner self-assessments improved significantly after using the proposed system ($t= -6.188$, sig of $t=0.000<0.05$). This indicates that most learners agreed that their English vocabulary abilities were enhanced after using the proposed context-aware ubiquitous English vocabulary learning system.

Table 15. The Paired-Samples T Test result of self-assessment English vocabulary ability

(a) Paired samples statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	3.867	18	1.5431	.3637
	after	5.272	18	1.6824	.3965

(b) Paired Samples T Test

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1 before - after	-1.4056	.9637	.2272	-1.8848	-.9263	-6.188	17	.000

Additionally, to further investigate whether learners significantly prefer the context-aware learning mode provided in the experimental group to the non-context-aware learning mode in the control group, all students in the control group were invited to use the proposed context-aware ubiquitous English vocabulary learning system for one week after finishing their learning activity and post-test. That is, the 18 students simultaneously experienced both the learning modes (i.e. without and with context-aware service), and then a questionnaire was designed to measure learners prefer which learning mode. Table 16 summarizes the questionnaire result. Among the 18 students investigated by the study, this study found that 72.2% of learners preferred to use the proposed context-aware ubiquitous English vocabulary learning system for English vocabulary learning. Meanwhile, 94.4% of learners agreed that using the proposed system with context-aware service could promote their learning motivation. More importantly, all students thought that the proposed context-aware ubiquitous English vocabulary learning system could help them develop a deeper impression of vocabulary than the mobile English vocabulary learning system without context-aware service. Additionally, 88.9% of learners are happy to learn other English curriculums using the proposed context-aware ubiquitous English learning system in the future.

Table 16. The preference comparison of both the learning modes

Question	The proposed system with context-aware service (%)	The proposed system without context-aware service (%)
Do you prefer to learn English vocabulary by the proposed system with or without context-aware service?	72.2	27.8
Do you think that which learning mode can promote your learning motivation much more?	94.4	5.6
Do you think that which learning mode can make your score progress much more?	61.1	38.9
Do you think that which learning mode can deepen your memorized impression on vocabulary much more?	100	0
If there are similar English learning activities in the future, which learning mode do you prefer to use again?	88.9	11.1

4. Discussions

In this section, how to integrate the proposed personalized context-aware ubiquitous English vocabulary learning system with the formal classroom learning is first discussed. Additionally, how to apply the proposed scheme to the vocabulary learning of any second languages is addressed. Moreover, the convenience of learning English vocabulary by mobile devices is also discussed herein.

(1) How to Integrate the Proposed Personalized Context-aware Ubiquitous English Vocabulary Learning System with Formal Classroom Learning

Since the proposed personalized context-aware ubiquitous English vocabulary learning system was designed to support informal English vocabulary learning during the two week learning activity considered in this study, all participating learners learned English vocabulary during their leisure time and without the assistance of teachers. Naismith and Corlett (2006) indicated that successful mobile learning should be integrated with formal classroom learning and the learning experiences of learners themselves. Indeed, the proposed ubiquitous English vocabulary learning activities could be further integrated with formal classroom learning activities and teacher can assist learner learning during learning processes. Performing this task requires teachers to implement curriculum planning and teaching strategies. However, to conduct this learning scenario requires the support of teaching materials, the learning location planning of schoolyard, the modification of teacher instruction strategy, and learner participation. The above considerations should be considered in properly integrating the ubiquitous learning process with formal classroom learning.

(2) How to Apply the Proposed Scheme to the Vocabulary Learning of any Second Languages

The personalized context-aware ubiquitous English vocabulary learning system proposed in this study can recommend appropriate English vocabulary to individual learners according to four contextual aspects. The experimental results demonstrated that the proposed system facilitates English vocabulary learning. Naturally, the proposed system can be applied to the learning of any language, with a corresponding difficulty parameter determined by Item Response Theory. Thus, the proposed learning mechanism offers an effective strategy for vocabulary learning in languages other than English.

(3) The Convenience of Learning English Vocabulary by Mobile Devices

Many studies have indicated that using PDA for learning activity is convenient (Davide Tosi &

Roberto Bisiani, 2007; Doug Vogel et al., 2007; Ogata, H. et al., 2006). In our experiment, the questionnaire responses indicated that few learners had experience of using mobile devices and accessing information through wireless network. See the data listed in Table 14(a). Numerous learners mentioned that access difficulties had prevented them from updating their learning portfolios or otherwise using the Internet, and these issues were not consistent with their expectation to be able to access the Internet everywhere. This reason may explain why the questionnaire results listed in Table 14(b) show that 17 % of learners disagreed with the notion that PDAs facilitated learning. However, all learners could successfully access the Internet from selected locations in the schoolyard, and thus learners were encouraged to update their learning portfolios at these places. Therefore, the successful ubiquitous learning activity should be based on sufficient coverage of wireless connectivity to enable learners to properly appreciate the advantages of mobile devices and wireless technology.

5. Conclusions

This study proposes a personalized context-aware ubiquitous English vocabulary learning system, which can recommend appropriate English vocabulary associated with providing context-awareness information to individual learners, to support effective English vocabulary learning. The proposed system developed a learner location estimation scheme based on back-propagation neural networks to support personalized context-aware ubiquitous English vocabulary learning. The accuracy rate in detecting leaner location exceeds 92%, which is sufficient to aid situational English vocabulary learning. The proposed personalized context-aware ubiquitous English vocabulary learning system was successfully implemented on PDA to facilitate a seamless ubiquitous English learning environment without constraints of time or place. Moreover, a nonequivalent pre-test-post-test group based on the quasi-experimental design was performed in a high school to assess learner learning performance after using the proposed context-aware ubiquitous English vocabulary learning system. The statistical results (F=5.785, sig of F=0.022) revealed that the learning performance of learners who used the personalized English vocabulary learning system with context-aware service is significant based on the assessment of the pretest and posttest, and exceeds the performance of learners who used the learning system without context-aware service according to ANOCA analysis. Additionally, the questionnaire analysis indicated that over 50% of learners achieve satisfactory learning experiences after using the proposed context-aware ubiquitous English vocabulary learning system. Furthermore, up to 72.2% of learners prefer English learning systems with context aware-service after experiencing two learning modes.

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國科會補助計畫衍生研發成果推廣資料表

日期:2011/10/15

國科會補助計畫	計畫名稱: 情境感知遊戲互動之合作式語言學習模式發展與學習成效評估研究
	計畫主持人: 陳志銘
	計畫編號: 97-2511-S-004-002-MY3　　學門領域: 資訊教育一電腦輔助教學

無研發成果推廣資料

97年度專題研究計畫研究成果彙整表

計畫主持人：陳志銘			計畫編號：97-2511-S-004-002-MY3				
計畫名稱：情境感知遊戲互動之合作式語言學習模式發展與學習成效評估研究							
成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	3	3	100%	篇	1.Chih-Ming Chen*, and Yi-Lun Li, ' Personalized Context-Aware Ubiquitous Learning System for Supporting Effective English Vocabulary Learning, ' Interactive Learning Environments., vol. 18, no. 4, pp. 341-364, 2010. [SSCI 收錄] 2.Chih-Ming Chen* and Shih-Hsun Hsu, ' Personalized

							2008. [SSCI 收錄] 3.Chih-Ming Chen* and Ching-Ju Chung, ’Personalized Mobile English Vocabulary Learning System Based on Item Response Theory and Learning Memory Cycle,’ Computers &; Education, vol. 51, issue 2, pp. 624-645, 2008. [SSCI, SCI, EI 收錄]
		研究報告/技術報告	3	3	100%		
		研討會論文	5	5	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	6	6	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	1.榮獲行政院國科會 99 年度吳大猷先生紀念獎。 2.榮獲政治大學 97、98、99 年度研究優良獎。 3.榮獲行政院 99、100 年度獎勵特殊優秀人才

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	2	1.全民英檢字彙及網路英語新聞教材典藏系統。 2.PDA 個人化行動英語字彙暨英語新聞閱讀學習系統。

項目	教材	1	全民英檢字彙及網路英語新聞教材
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

　　□實驗失敗

　　□因故實驗中斷

　　□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

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技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

在 Educational Technology & Society、Computers & Education 及 Interactive Learning Environments 各發表一篇期刊論文。

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

利用試題反應理論(Item Response Theory)依據學習者的測驗狀態來動態評估學習者的英文字彙能力，並依據學習者的個別能力挑選合適於個人難易度的英語字彙，協助學習者進行有效的個人化英語字彙學習。並且在考量單字的長度、音節及在全民英檢中的字彙歸類等級因素，提出一個適合於評估英文字彙難易度的新方法，並且應用所評估出來的個人字彙能力及每個英文單字的難易度，提出一個 記憶週期法(Learning Memory Cycle Scheme)可以由學習系統找出每一個人對於每一個英文單字的動態記憶週期，並運用找出來的記憶週期適切的安排英文字彙的複習時機。以上所提出的學習及複習策略可以達到相輔相成的英語字彙學習效果，並且這樣的學習機制已經被實際開發在 PDA 掌上型電腦上，方便學習者進行無所不在的英語學習。而實際開發系統也已經被應用於大學英語系學生的英語字彙學習上，在長達五週的實驗中經過嚴格的統計驗證其對於英語字彙的學習具有極高的助益，特別是因應個人字彙記憶週期的複習方法，對於提升字彙的學習非常具有幫助。本研究所開發的學習機制非常適合與目前的電子字典進行結合，讓電子字典具有輔助個人學習英文字彙的個人化學習及複習機制。