Constructing a User-Friendly and Smart Ubiquitous Personalized Learning Environment by Using a Context-Aware Mechanism

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Abstract—Although m-learning applications have been widely researched, few studies have investigated applying adaptive learning content to various learning environments and efficient input interfaces. This study combined a context-aware mechanism, which can be used to provide suitable learning information anytime and anyplace by using GPS technology, with a rapid and user-friendly QR code interface input into a personalized context-aware recommendation (PCAR) learning system for enabling learners to immediately save useful external contents as learning materials. To improve students' English application abilities efficiently, GPS combined with an intelligent personalized context-aware learning algorithm was used to obtain English learning content that is more practical. The results of several experiments and investigations indicate that the posttest grades of the experimental group, which used the proposed PCAR system, were higher than those of the control group. Furthermore, approximately 80 percent of the users were satisfied with how the system benefited their learning and with its ease of use. The results also show that the PCAR system markedly enhanced learner interest and learning efficiency by creating a convenient virtual English learning environment.

Index Terms—m-learning, GPS, QR code, personalized recommendation system, Context aware learning, PCAR

1 Introduction

The continual innovative progress of various types of mobile equipment have led to a boom in m-learning [4] with the aim of creating a learning environment unrestricted by temporal or spatial factors that can afford suitable information anytime and anyplace [7]. Some studies have investigated m-learning to explore the characteristics of appropriate learning content at the most appropriate time and place. Numerous studies have also been investigated methods for constructing a learning environment unrestricted by time and space that can support learning [5], [26] to ensure that learners can access interesting learning information anywhere through mobile devices. Other studies have investigated methods for collecting the learning records of learners by using mobile devices and analyzing the data to facilitate learning in high school physics and chemistry courses [25], [28], [29], [30]. These studies have established a ubiquitous virtual learning environment supporting precise learning information according to the habits and interests of various learners, providing appropriate learning content anytime and anyplace [2], [4]. Moreover, these studies have advanced m-learning, enabling virtual instruction that provides learning materials that facilitate efficient student self-learning.

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Although studies related to m-learning have obtained considerable results in m-learning applications, few studies have explored the relationship between learning demands and changes in learner surroundings; that is, although learning demands are related to the personal interests and English ability of the learner, learning demands also frequently vary according to the learning environment [9], [14], [19]. Therefore, the Please avoid using the ambiguous and subjective adjective "right" in academic writing. Option: "most appropriate"optimal learning content must be provided to learners according to their individual learning conditions and environment [7], [12], [13]. The learning content provided by a system can change as the learner's location and environment change; such dynamically adjusted learning provides a location-based learning mechanism to learners. In some studies, this approach has been classified as *ubiquitous learning (u-learning)* to differentiate it from the typical m-learning approach. This study used the broadly defined term *personalized mobile learning* (m-learning). Because of the various sensor technologies used with mobile equipment, personalized m-learning has gradually become an extension of and a new learning style for e-learning or distance learning. In addition, detecting the location of the learner can further refine the personalized learning objectives according to the learner's environmental information such as nearby buildings and regional traits, history, and customs in m-learning. Thus, the greatest advantage of personalized m-learning is that it provides optimal real-time learning content to individual learners. For example, in foreign language learning, reciting vocabulary and conversational phrases is necessary; however, understanding and applying the learned information can be particularly challenging. Therefore, the crucial aim of integrating learning content and fragmented memories into the real environment is our main research motivation in enhancing language learning efficiency.

This study exercised context-aware transformation learning rules to support the operation of an active recommendation learning mechanism. This recommendation learning mechanism differs from those of previous studies, which have primarily focused on only transferring GPS location information and recording personalized learning behaviors to identify appropriate learning materials for individual learners [2], [24]. This study integrated a context-aware technique and algorithm into the proposed personalized recommendation learning subsystem, which focuses on combining personal environmental information with learning behaviors and experiences, to determine the appropriate learning materials for a learner at a specific location. This technique can facilitate focused m-learning and ubiquitous computing (i.e., provide optimal learning content at the most appropriate time and place to every learner), thereby enhancing learning interest and efficiency through mobile devices. The proposed system can be used to guide the main learning direction of individual learners by supporting practical learning content that is related to environmental information detection that is context-aware, and by enhancing the effectiveness and efficiency of m-learning.

To overcome the limitations and disadvantages of previous m-learning research, this study developed an intelligent personalized context-aware recommendation (PCAR) learning system that comprises a *multimedia learning streaming subsystem*, *context-aware learning subsystem* created by integrating a context-aware GPS and QR code interface [1], [16], and *mobile learning recommendation subsystem*. In summary, the purpose of this study was fivefold: to develop an integrated m-learning system which supports the aforementioned learning functions, so that it can be applied in daily activities; to challenge the traditional concept of teachers, students, and hardware equipment in classrooms; to incorporate network technology applications for enabling diverse and enjoyable self-learning that can enhance learning momentum in learners; to facilitate e- and m-teaching; and to enable learning unrestricted by time and space.

2 Related Studies and Applications

This research mainly focused on combining a context-aware mechanism with GPS technology and real-time analysis m-learning techniques to create a ubiquitous learning environment. This learning environment was established to enhance the learning willingness and effectiveness of students. The following sections explore current m-learning applications and context-aware learning theories that have been increasingly applied in various learning fields.

2.1 M-Learning

Following the rapid development of wireless network and mobile technologies, numerous research outcomes and applications for m-learning and ubiquitous computing have been proposed. Providing "more suitable content" at "the right time and place" has consistently been the focus of distance learning fields such as e-, m-, and u-learning [6]. Thus, mobile devices have shifted from platforms for communication and entertainment to having a comprehensive multipurpose role in mobile office, mobile commerce (m-commerce) [21], and m-learning functions. The basic aim of m-learning is to enable learners to obtain the desired learning information from remote servers or databases (DBs) through mobile devices, without being limited by time or place. Therefore, some In this context, "research" is a noncountable noun; therefore, it receives no plural marker (that is, "-es").studies have classified advanced m-learning as u-learning. The learning information that u-learning provides is generally study content related to the learner's present environment, efficiently reducing the excessive amount of learning material and information provided by typical m-learning [34]. The personalized learning information service of advanced m-learning, or u-learning, has become a common research topic in ubiquitous computing. Furthermore, cloud-side services have prompted the rapid development of ubiquitous computing. By the ubiquitous transmission of wireless and mobile communication networks and the increasingly wide functionalities of mobile devices, numerous mobile applications have collocated all types of ubiquitous computing services to support numerous customized information-access services such as those related to telecommunications, marketing, traveling, exhibition navigation, health care, and learning. For example, Ogata and Yano proposed the JAPELAS and TANGO systems for enabling learners to learn Japanese efficiently by accessing virtual context-aware learning information in real-world situations [3]. Staudt experimented with and investigated young students who were learning to use handheld computers [30]. The students used temperature probes attached to handheld computers to collect data from the air and water and then compared and analyzed the information immediately. This field teaching and learning approach can stimulate children's curiosity about learning.

In addition, combining the analysis and storage advantages of web-based learning systems with the real-time data collection feature of mobile devices has become a vital learning application. This type of learning is frequently applied in natural science and bioscience programs that require processing observations during outdoor learning courses. Seng investigated how PDA devices affected the learning of elementary school students [27]. The students observed outdoor objects and input the information into PDAs. Because the devices were equipped with GPS, the entered data could be easily connected to the students' locations. In conducting outdoor instruction, teachers provided the required course materials for learning through a wireless network, while the students exchanged information with the teachers through wireless PC cards in the PDAs. The students used their wireless access to download related learning information of specific locations from the teachers' devices and then saved their learning outcomes or used a camera to record the observed scenery in their PDAs. Moreover, the learning behaviors of individual students were recorded and analyzed. Therefore, each student received suitable learning content through a wireless network during outdoor learning activities [17], [18].

Personalized service, wireless sensor networks, Web 2.0, and new interactive multimedia technology have been developed for applications in e-, m-, and u-learning [20], [22]. However, perceiving learners' actual needs according to their location and environment is essential for effectively combining their learning activities with virtual learning content. In addition, the inconvenient input problem must be addressed to improve m-learning.

2.2 Context-Aware Learning

In situational learning theory [10], the context-aware (scenario-aware) concept, proposed by Theimer in 1994 [37], focuses on transmitting proper information to each user according to individual needs through various types of sensors appropriate for different external circumstances.

When situational learning theory is applied to the practical m-learning system, providing suitable learning materials to learners requires addressing the specific "Requirements" is an ambiguous term in the context of "learners". As you know, "needs" is frequently used in education to refer to the various accommodations, modifications, materials, and goals necessary for a learner to progress. Hence, "goals" might be appropriate in this context.needs of individual learners, who encounter different situations anytime and anyplace [11], [33]. For example, Chen and Huang proposed a context-aware ubiquitous learning system (CAULS) based on RFID, wireless network, embedded handheld device for detecting and examining real-world learning behaviors of students in order to provide proper aboriginal education course learning material [5]. However, changes in the needs of a learner are frequently influenced by the involved surroundings, which are unique to each learner's location. Therefore, the relationship among a learner's location, environment, and information demand must be observed [27], [31]. These approaches can enable mobile devices to detect a user's current location for determine its corresponding environmental information and provide appropriate learning information; this technology has already been applied in some exhibition navigation systems (e.g., those in fine arts museums, large-scale exhibitions, campuses, and resorts) and language and natural science courses [32], to provide personal information services to users. Hence, in m-learning systems, transforming mobile users' location data into the environmental information relevant to users is the main purpose of context-aware mechanisms aimed at providing appropriate content to individual learners. Some learning studies have focused on designing an automatic adjustable learning mechanism that delivers relevant and appropriate learning material to users who are in various places and have unique demands [35], [36], [38].

Therefore, to improve on the aforementioned m-learning studies limited by the disadvantages of learning information overload, this study incorporated QR code and GPS technology into a user interface management module. In addition, after the learner's location is determined, the relevant environmental information can be identified using a *context-aware module* to assess the learner's current environmental information, such as that involving buildings, nearby landmarks, and regional traits, in addition to the corresponding learning material of sites. The module is then combined with a *learning-log* function to record and analyze the learning conditions of individual learners in each learning process. Finally, by coordinating with the dynamic context-aware learning mechanism, the *personalized recommending learning* mechanism provides customized m-learning materials to learners.

3 Framework of the Intelligent Personalized Context-Aware Recommendation M-Learning System

This study adopted 3G mobile communication and GPS networks featuring extensive signal coverage as the network architecture for message transmission. These networks were combined with the operational mechanisms of the context-aware module and course material recommendation mechanism for immediately determining potential user demands according to the user's environment and learning records, and thereby recommending suitable learning content obtained from a course material DB for learners engaged in English multimedia learning. The following sections present the architecture of the proposed system and the relationships of the learning functions among the main modules of the system.

3.1 System Architecture

The PCAR learning system was developed by combining a user-friendly QR code input operation interface, wireless network technology, a location management mechanism featuring GPS technology, and personalized data mining technology. The system was developed to provide customized context-aware learning information to individual learners and create a ubiquitous English learning environment. The architecture of the system is divided into three main parts: 1) a *multimedia learning subsystem*, in which all English courses, various learning materials, and learners' learning behaviors are stored to provide students with multimedia learning information through a streaming server for English m-learning; 2) a *context-aware subsystem*—supported by GPS, QR code data preprocessing, and an input module—that determines and labels the relationship between learning content and an environment; and 3) a *mobile learning recommendation subsystem* that comprises learners' authentication and personalized mobile recommendation agents to determine the learning content that is most appropriate for learners at a particular location and time. Fig. 1 depicts the learning functions of these three subsystems and their interrelationships.

In this research, instant learning messages were transmitted to handheld or mobile devices through 3G mobile communication networks or wireless networks. This mode of transmission enables users at various locations to receive desired information anytime and anywhere. First, learners must login the personalized learning system featuring the context-aware recommendation mechanism. Learners can operate the user-friendly personalized learning interface by using QR codes and GPS technology (Fig. 1) to input or output their intended external learning messages quickly through the encoding or decoding function and preprocess and transfer their GPS location information. The records of the learners' learning behaviors are saved in the personalized learning DB (Steps 1 and 2 in Fig. 1) and then fed back to update the context-aware subsystem, enabling it to provide abundant environment-related learning information to learners (Step 3 in Fig. 1). Furthermore, relevant information can be extracted nearly instantly through a QR code hyperlink. Thus, in addition to simplifying the original, inconvenient input–output approach to m-learning, the current system analyzes learning records by using *learning-behavior-analyzing*

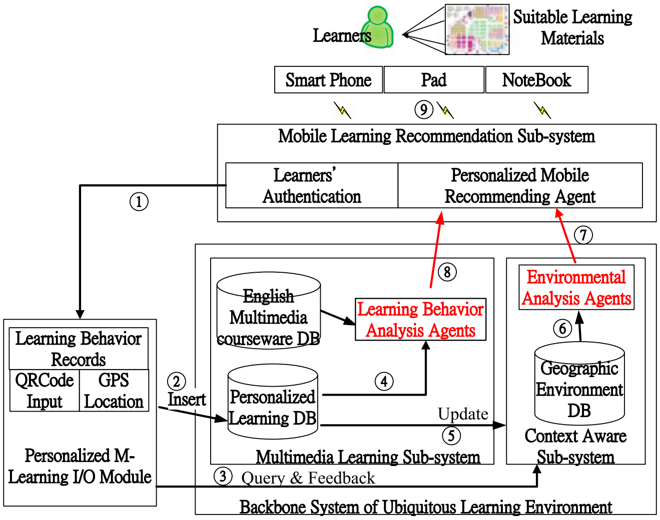

Fig. 1. System architecture of the personalized context aware recommendation learning system.

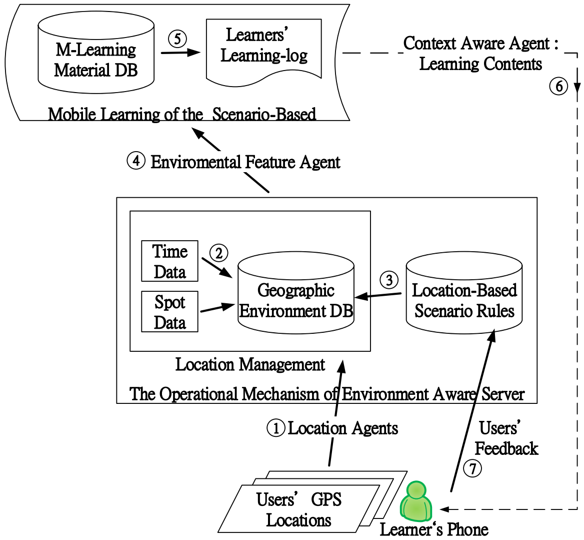

Fig. 2. Recommending operation processes of context-aware sub-system.

agents, obtaining the newest learning statistical results to update the context-aware subsystem (Steps 4 and 5 in Fig. 1). Thus, the learners' interests and learning behaviors relevant to the learning process at any location can be correctly ascertained and classified.

Second, by operating in coordination with the location management and scenario analysis mechanism of the context-aware module, the proposed system can identify the position of each learner, identify useful and effective learning materials, and send the materials to the learners according to the learners' locations, thereby saving time generally spent searching for learning content. Thus, each learner can obtain learning materials related to their location through the location-scenario transformation rules of *the environmental analysis agents* (Step 6 in Fig. 1). The mobile learning recommendation subsystem evaluates the learners' current environmental information (such as scenic areas, tourist attractions, museums, and cultural centers), learning conditions, and attributes of the type of learning scenario, which represent the possible learning interests and preferences determined by detecting the personalized mobile recommendation agent (Steps 7 and 8 in Fig. 1). The appropriate learning materials for various learners are then ascertained and sent to the learners' mobile devices (Step 9 in Fig. 1). Finally, a learner- can obtain the recommended m-learning courses anywhere through the mobile recommendation mechanism (Fig. 1).

3.2 Context-Aware Subsystem

This paper presents a personalized m-learning system with a context-aware recommendation mechanism comprising three subsystems, the core of which is the context-aware subsystem. The functional and utilitarian aspects of this module are introduced in the following two subsections.

3.2.1 Context-Aware Learning Module with GPS and QR Codes

The context-aware module was incorporated into the proposed system to provide environment-specific real-time learning materials. After conducting comprehensive location-aware analysis according to the user location, time, and environmental information, this module determines the category of learning information according to the learner's current location factors, and then filters suitable m-learning course materials by using the environmental feature agent, thereby facilitating environment-aware learning (Fig. 2).

The main operation mechanism of the context-aware learning module is performed using the *intelligent personalized context-aware learning* algorithm, which is auxiliary to the scenario-learning goal (context-aware learning), for satisfying the practical English learning demands of learners in various environments. The IPCAL algorithm entails the following four main judgment rules and processes:

- *Phase 1: Location identification:* The current location of each learner is detected through a GPS *location agent* (Step 1 in Fig. 2); thus, the learner's position on a map is determined.
- *Phase 2: Location management (LM):* After the learner's position data are received through the location agent, the LM is used to analyze the learner's current surrounding environmental features from a geographic environmental DB according to location-based scenario rules (Steps 2 and 3 in Fig. 2). Data mining is used to classify the learner location into the proper geographic environmental DB and to determine the corresponding environmental information.
- *Phase 3: Context awareness and judging for learning:* The environmental feature agent can detect a learner's environment and its relationship with environmental information that is associated with the learner's location information, providing a comprehensive learning recommendation to learners according to the environmental features of their location (Step 4 in Fig. 2). Finally, this module can filter the mobile learning materials from the m-learning material DB according to the learner's position and then refer to the previous learning records in the learner's learning-log (Step 5 in Fig. 2) for providing the learner with the most suitable learning content package through the context-aware agent, thus satisfying the learner's learning demands (Step 6 in Fig. 2).

(a) : Learner's reading access records

Learner_ID	Learning_Content_ID	Reading_date	Reading_time	Reading number
A0353010	course-conv-07-003	2012-May-14	10:00	1
A0353010	course-conv-07-008	2012-May-15	11:30	2
A0353012	course-idiom-07-005	2012-May-12	15:37	2
A0353014	course-word-08-004	2012-May-14	17:25	4
....	....	....	....	....

(b) : The attribution of the type of learning scenario based on learner's environment

Enviro_area_ID	Location_scope	Time-slice	Learning type	Learning_Doc
Taipei_SL_0001	(25.141,121.541)~ (25.142,121.542)	Morning	course-conv	07-001
Taipei_SL_0002	(25.145,121.548)~ (25.147,121.550)	Noon	course-conv	07-002
Taipei_SL_0003	(25.154,121.552)~ (25.157,121.554)	Afternoon	course-idiom	01-005
Taipei_SL_0004	(25.134,121.544)~ (25.137,121.548)	Morning	course-assay	03-001
Taipei_WH_0001	(25.033,121.500)~ (25.035,121.503)	Evening	course-word	05-002
....	....	....	....	....

(c) : The recommended proper learning contents by recommendation subsystem

Learner ID	Current_location	Access time	Interested type	Recommended_ID
A0353010	25.141089,121.54124	10:35	course-conv	Cour-conv_07_001 Cour-conv_07_002
A0353012	25.146994_121.55392	12:25	course-idiom	Item-idiom_01_005
A0353014	25.034679_121.50132	17:19	course-word	Cour-word-05-002
....	....	....	....	....

Fig. 3. Learning content recommended to learners by context-aware mobile learning subsystem.

- *Phase 4: Reading and testing in the learning and assessment phase:* Learners can read the personalized learning materials immediately on receiving them on their mobile device from the context-aware agent in Phase 3. The system then creates a quiz comprising questions about the recently provided learning content. The questions address keywords derived from the learning materials to determine whether the learner comprehended the content
  - ○ *Phase 4.1: Passing the quiz:* If the learner passes the quiz, he or she would receive other related and extended learning information. In addition, the learner would be prompted to provide a feedback value for the provided materials according to the appropriateness of the content and their overall satisfaction (Step 7 in Fig. 2). This feedback facilitates continual adjustment of the context-aware recommendation learning mechanism.
  - ○ *Phase 4.2: Not passing the quiz:* If the learner does not pass the quiz, he or she would be prompted to review learning content that is more basic than the originally provided content. This phase enables learners to improve comprehension.

In summary, this module records the selected learning situations and learning time of learners. The records are then fed back to the location-based scenario DB as references for rule revision after the learning situation is analyzed. The IPCAL algorithm is then used to determine the type of environment of a learner's current location. Moreover, the IPCAL algorithm is used in conjunction with the learner's learning-log records to analyze the learning demand and degree of comprehension after the scenario learning information of learners is recorded. This analysis facilitates ascertaining the learning weaknesses of individual learners that must be improved through differential learning by using the system's context-aware module. In addition,

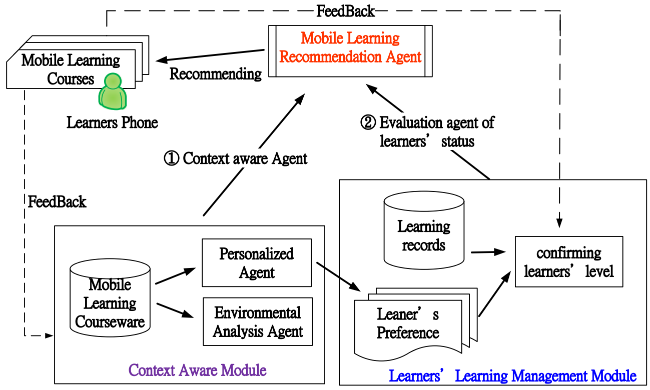

Fig. 4. Operation processes of mobile learning recommendation sub-system.

teachers can determine the status of students' overall learning, and then adjust course materials at different levels to effectively enhance learning interest and efficiency.

3.2.2 Recording Learning Activity and the Recommendation Mechanism Module

All learning activities and actions are detected and recorded by different mobile learning agents. After preprocessing original learning data and analyzing the relationship between the m-learning materials and locations, as shown in Figs. 3a and 3b, the environmental feature agent determines the proper scenario learning content according to the learners' current environmental information and the corresponding type of environment, as shown in Fig. 3c. First, all learning actions, such as click-through records, reading time and reading number, are recorded in the learning-log of the personalized learning DB (Fig. 3a). Second, the learners use the QR code input interface to instantly store all types of new learning information that is correlated with the location information (Fig. 3b),. Thus, the environmental information of each area accumulates learning materials that belong to different learning types. Finally, the context-aware agent filters the appropriate corresponding m-learning course materials from the mobile learning courseware DB for learners according to the context-aware and individual recommendation mechanism (Fig. 3c).

3.3 Mobile Learning Recommendation Subsystem

The mobile learning recommendation subsystem module comprises two groups of recommendation parameters: a learner's current learning status and the relevance of online learning course materials. The learning statistics of each learner is provided as recommendation conditions to the m-learning recommendation server. The related course materials that suit the learner's current learning status and progress are then provided (Fig. 4).

In general, the learning management module (Fig. 4) contains the individual learning records of each learner (e.g., the English course materials learners have viewed, questions that were answered incorrectly, and inquired data) and the individual learner's preference (personal interests and habits) as the personalized environmental parameter. The next step is confirming the learner's learning level to determine more accurately the current learning demands of learners as

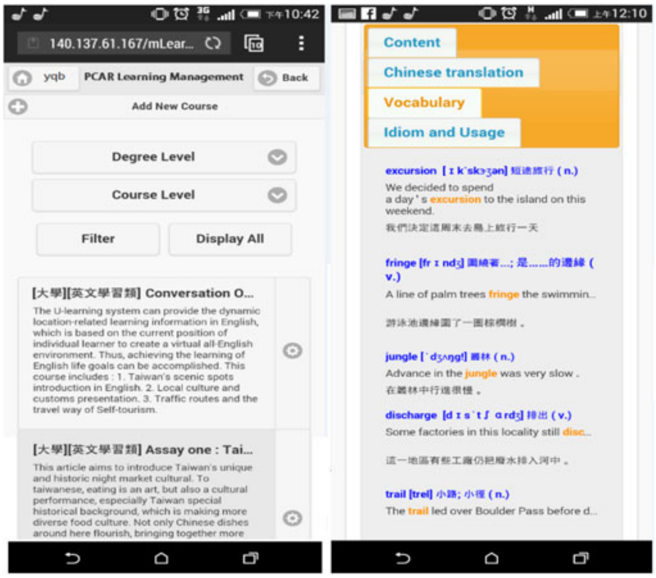

Fig. 5. Intelligent mobile learning functions and interface of the PCAR learning system.

one of the final recommendation parameters. The PCAR recommendation algorithm uses the learning records and personal preferences to evaluate learners' current learning situation and progress. In addition, the algorithm consolidates the relevance of various course materials by using the usage rates of teaching materials from the course management module to determine the knowledge structure correlation of English learning content provided by English teachers and records of learner reading course material.

Finally, the recommendation subsystem analyzes the aforementioned learner learning management module and information consolidated from the course management module by combining the *evaluation agent of learner status* and *context-aware agent* (as ① and ② of Fig. 4). This analysis is performed to provide customized recommendation learning content to individual learners according to the evaluated conditions of the m-learning recommendation agent.

In this study, the main module functions of the system were developed according to specific m-learning requirements and user satisfaction survey results after the system was applied to actual m-learning. Therefore, this intelligent personalized context-aware learning system affords four major learning functions through which learners can observe four learning segments: m-learning, mobile video, QR codes, and recommended learning content (Fig. 5).

4 Experimental Design and Result Analysis

A total of 102 first-year undergraduate students participated in this experiment spanning three months (one academic quarter). The students, who were grouped randomly (rather than according to competence) into two classes, belonged to the colleges of Liberal Arts, Law, and Business Administration at Chinese Culture University in Taiwan. The students were willing to participate in this study because they expressed a desire to improve their English learning. The training offered in this study involved after-school tutoring and extracurricular activities aimed at assisting students who were underperforming in the classroom. The sample was divided into two groups according to the classes: an

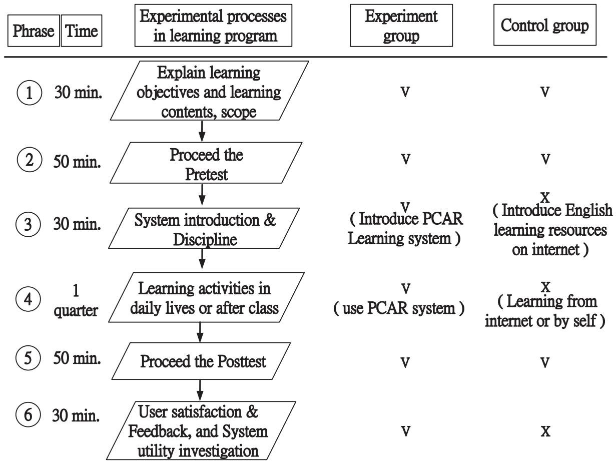

Fig. 6. All experiment processes and learning activities between the experimental and control group.

experimental group and control group. Experiments were conducted to compare and evaluate the difference in the learning effect and style and to investigate user satisfaction regarding system utility. The experimental group, comprising 57 students, tested the proposed PCAR learning system containing the context-aware recommendation mechanism for assisting them in all types of real-life English learning including situational conversations, real-time essays, cloze quizzes, and vocabulary acquisition. The control group, comprising 45 students, used only computers or mobile phones to search the Internet for English learning materials. All English learning materials and learning interface arrangements were designed by senior teachers experienced in teaching English or by e-learning experts. The teachers were faculty members in the Chinese Culture University Department of English Language and Literature or Department of Information Management. Each group was individually analyzed at the beginning of the study and after three months of using their assigned learning method.

The students in the experimental group continually received English learning content recommendations through their smartphone when their surroundings changed. All learning behaviors were recorded in individual student learning-log, which were used to analyze student learning preferences and tendencies. Such learning-log facilitate the precise recommendation of suitable learning materials. Throughout the three months, posttest examinations were administered to the two groups by using independent *t* tests to evaluate the effects of the learning methods on English learning, including daily vocabulary, phrases, and conversation. In addition, user satisfaction was investigated in the experimental group to examine the various aspects of the system's utility, including operational ease, interactivity, and practicability. The following sections discuss the results of the experimental programs.

4.1 Experiment Design and Learning Activities

The English learning materials that the senior English teachers provided to the students included vocabulary, idioms, conversations, and essays. The learning content was labelled according to various environmental properties to ensure that the relationship between the learning content and location was consistent. The experiments were

Fig. 7. Students in the experimental group use the personalized context-aware recommendation learning system.

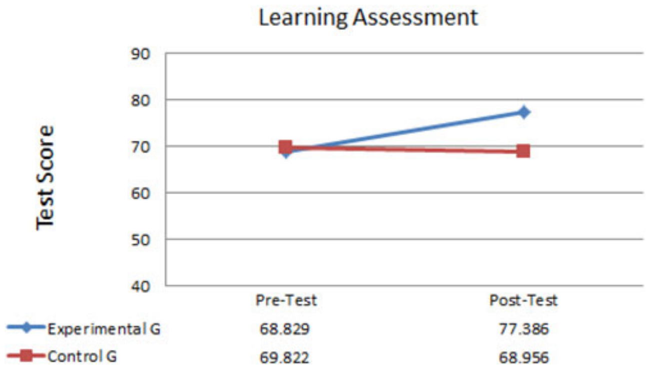

Fig. 8. Learning assessment comparison of the pre-test and post-test between the experimental and control group.

conducted to evaluate the learning effectiveness and influence of learners' learning willingness according to the QR code, context-aware, and personalized recommendation learning modules. Fig. 6 shows the experimental process of the learning activity programs. Phase 1 involved explaining the learning objectives and content to the two groups. Next, in Phase 2, a pretest was administered to record and evaluate the average English level of the students in both groups. In Phases 4 and 5, the different learning methods were distinguished. The first method involved using the PCAR learning system, which enabled the experimental group students to learn English in daily life during the three-month study period. The second method entailed using traditional learning methods (e.g., using Internet resources) to teach the control group students. Fig. 7 illustrates the learning situations of the students in the experimental group who used the PCAR learning system. A posttest was administered to determine any apparent difference in learning effectiveness between the two groups. In Phase 6 (Fig. 6), a user satisfaction questionnaire, which mainly included questions regarding the operational, interactive, and practicability of the PCAR learning system, was administered to examine and adjust the system's learning functions and ascertain its learning effects and system utilities.

The rapid input-output interface functions were based on QR code encoding and decoding technology, thereby greatly enhancing the input and output processing speed. Therefore, this user-friendly I/O interface enhanced the students' learning interest because they used the QR code input function to obtain English learning content relevant to their surroundings. Regarding evaluation of the learning effects of the context-aware module, feedback questions were devised to determine the context-aware learning results analyzed according to GPS location information. The location was used to derive the learners' current environmental messages and provide them with relevant learning materials. Regarding the personalized recommendation learning module, the experimental group learner satisfaction questionnaire was administered after the students used the PCAR learning system. This study focused on the feedback and responses of those who not only received but also accessed the recommended multimedia learning. The following sections discuss the experimental results.

4.2 Results and Discussion

Four aspects of the learning performance assessment experiments and questionnaire were examined: practical learning, learning satisfaction, ease of use, and learning effectiveness. The questionnaire involved a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

4.2.1 *Learning Performance Assessment*

In the pretest and posttest, the students answered questions pertaining to various types of daily situational conversations and English essays to assess whether the two groups exhibited dissimilar English learning progress. The posttest results indicated that the students in the experimental group had progressed more than the students in the control group did. In other words, the group in which the students used the PCAR system to learn English scored higher on the posttest (mean = 77.386) than did the control group (mean = 68.956), despite the average pretest score of the experimental group being slightly lower than that of the control group (Fig. 8). The independent sample t test results for the two groups revealed a significant difference ($t = 2.510, p = .014 < 0.05$) between the pretest and posttest scores of the students in the experimental group who used the PCAR system. The large difference between the pretest and posttest results indicated that the learning effect in the experimental group was greater than that in the control group. Moreover, according to the standard deviation (SD) values from the experimental group pretest and posttest, both SD values (15.00484 and 15.13482, respectively) were similar, indicating that the discrete degree of student scores in the experimental group was highly similar in both tests. Thus, the comparison of the mean value of the pretest and posttest scores was credible and meaningful. In contrast to the experimental group, no significant difference was present in the control group (Table 1). The average pretest score of

TABLE 1
Pretest and Posttest Values of Experimental and Control Groups

Group	Test	Students (N)	Mean (M)	Standard deviation (SD)	Standard Error (SE)
Experimental	Pre-test	57	68.829	15.00484	1.98744
	Post-test	57	77.386	15.13482	2.00466
Control	Pre-test	45	69.822	15.95489	2.37841
	Post-test	45	68.956	18.79187	2.80133

the experimental group was slightly lower than that of the control group. Therefore, as shown in Table 1, the English ability improvement range on the posttest of the experimental group was wider than that of the control group. In other words, after 3 months, the conversational, vocabulary, and reading comprehension abilities of the experimental group progressed more than those of the control group did.

These improvements in English learning exhibited by the students in the experimental group were further analyzed by dividing the students' pretest grades into three subgroups according to score sequence. The results suggested that each third of the subgroup students progressed more on the posttest than on the pretest (Fig. 9). However, the greatest posttest score increase (34.7 percent) was achieved by the bottom third of the students of the experimental group, who obtained the lowest average pretest score (52.7) in the experimental group. The average posttest score of the bottom third of the control group was only 51.8, revealing that there was almost no change in learning effects. Thus, learning without the PCAR system produced similar learning outcomes because these learners lacked suitable auxiliary. By contrast, the experimental group students who scored poorly on the pretest progressed notably by using the PCAR system, according to the posttest results. The middle third of the experimental group students also progressed noticeably. The relatively slight progress by the top third of the students was probably because the tests involved using the item facility index, which is intended for testing students with only basic or general English ability. Thus, we suggest that English materials should include learning content that is more advanced. The findings indicate that the context-aware recommendation mechanism of the PCAR learning system was more beneficial and effective for the students with lower English abilities than for the students who originally exhibited "Acceptable" here implies that the other group's abilities were "unacceptable", which is inappropriate in an education context.higher English abilities.

The learning effect of the system on all the experimental group students was investigated according to student evaluations of the learning effects. This method enabled ascertaining the honest opinions of the students about the English learning effect. The evaluations of the PCAR system were gathered to determine whether the context-aware learning mechanism and active recommendation learning function facilitated improved learning. Therefore, the self-evaluation questionnaires were designed to enable students using the PCAR system to describe their English learning effects in detail through reviews and self-comparison. The extent of the influence of the learning effect was divided into five ranks by using a 5-point Likert scale, where 1 = *strong disagreement* and 5 = *strong agreement*. Five types of feedback on the learning aspects were provided:

1. *TA (Teaching Approach)*: This teaching approach can enhance my learning efficiency and English abilities.
2. *LM (Learning Material)*: The learning materials are becoming more enjoyable and practical.
3. *CALI (Context-Aware Learning Interactivity)*: Providing context-aware learning content can enhance interactivity and promote my active-learning willingness.
4. *RLM (Recommendation Learning Mechanism)*: The recommendation learning mechanism supports personalized related learning content, which is extremely beneficial and useful.
5. *PCAR-DGL (PCAR Demand Guiding Learning)*: PCAR can satisfy my current demands and guide my learning by adjusting my learning content sequence dynamically.

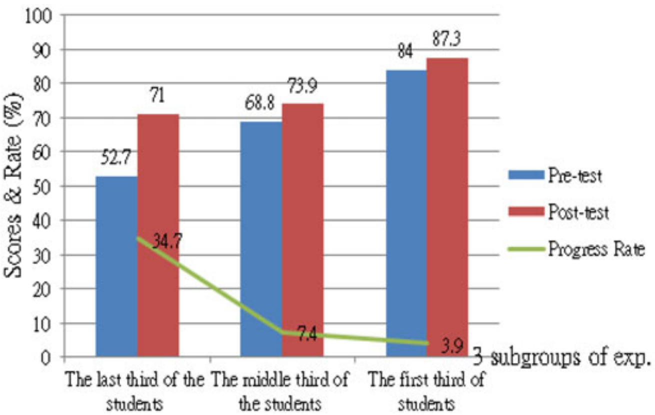

Fig. 9. Scores of pre-test and post-test of experimental group and the rates of progress for each subgroup, which is divided into three subgroup according to the descending order of pre-test scores of the experimental group students.

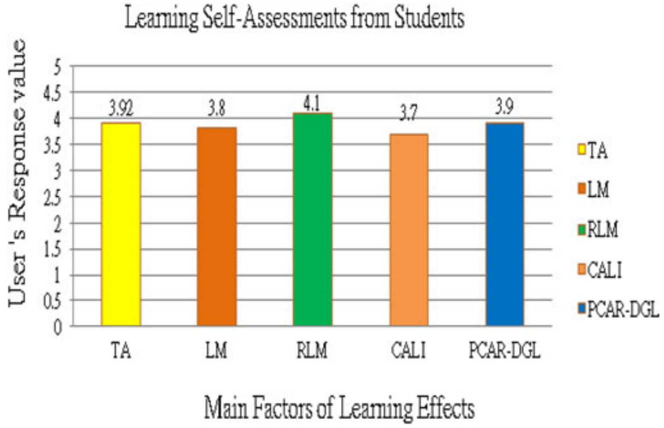

Fig. 10. The self-evaluations of experimental group in learning effect after they are using PCAR learning system about one semester.

TABLE 2
Mean and SD of Experimental and Control Groups in Learning Willingness and Interest

Type No.	Statements	Evaluation type	Mean ± SD
T1	Actually clicked and reading other related learning materials under recommending learning mechanism	Learning willing	4.25 ± 0.72
T2	To intrigue more learning interested and fragmentary time to absorb the life English under the active context aware learning mechanism.	Learning interested	4.31 ± 0.68
T3	Browsing other related learning contents through the context-aware and recommending module.	Learning motivation and interactivity	4.23 ± 0.62

As shown in Fig. 10, the *RLM* received the highest agreement rating (average satisfaction value, 4.1), indicating that the students considered the *RLM* to be extremely beneficial and useful. The feedback also indicates that the students believed that customized recommendation functionality could elicit interest in studying relevant material and facilitate English learning efficiency improvement. Furthermore, the *TA* and *PCAR-DGL* values, which relate to TA and guided learning, respectively, drew positive feedback from the students (the lowest average value was 3.9). This indicates that the PCAR system provided suitable learning content to satisfy the varied demands of individual students. The *LM* and *CALI* exceeded the average value (3.7), indicating that the dynamically adjustable learning content based on environmental factors was practical and enjoyable for students. The *IPCAL* algorithm of the PCAR system is consistent with scenario-aware teaching theory and can facilitate the development of personalized information services. Therefore, the advantages of the PCAR system are crucial for improving English learning.

Regarding active learning willingness and learning interest, the survey results (Table 2) indicated that the learners' click records and responses in reading related learning materials suggested by the recommendation mechanism of the PCAR system were nearly all positive and satisfactory. Specially, the response to T1 (mean = 4.25) verifies that the system significantly enhanced active learning willingness and behavior. In addition, the responses to the questions pertaining to the T2 item suggested that the students who used the PCAR system were willing to spend more of their idle time learning English and enhancing their interest in English; potential learning interest improved following context-aware learning guidance (mean = 4.31). The response to T3 revealed that the key factor in facilitating effective English learning is determining an approach that stimulates learner motivation to engage in self-learning. The response results indicated that learners using the PCAR system frequently accessed other related learning content, suggesting that the learning motivation of the learners using the PCAR system was enhanced (mean = 4.23). The p values of all types of satisfaction surveys were less than 0.01, indicating that the PCAR system significantly enhanced students' learning willingness, interest, and motivation.

In addition, this study examined learning effectiveness and practical application abilities to explore the differences in the students' actual cognitive and subjective evaluation in learning when using the PCAR system (Table 3). Regarding learning effectiveness, the survey results suggested that, for item I1, the level of agreement regarding the usefulness of the system in retaining English vocabulary and conversation was $74.9\% (= 22.6\% + 52.3\%)$ in the experimental group. In other words, nearly three-quarters of the students thought that learning English by using the PCAR system benefitted their learning and enabled them to apply English more in daily life. Moreover, the 73 percent positive response rate for item I2 (Table 3) indicates that most students felt that the PCAR aided them in enhancing their learning efficiency and cultivating their English application ability.

4.2.2 Effects of the Main Learning Modules and Actual Learning Satisfaction

Table 4 lists the users' learning satisfaction survey results pertaining to the PCAR system learning modules, indicating that the context-aware module obtained the highest affirmative rate (76.6 percent) in response to item I1. The results suggested that the learners believe receiving dynamic and appropriate English learning messages greatly benefits their learning. In addition, the results indicated that varying the instant learning content according to individual learners' environment was considered to benefit the deep memory aspect of the m-learning users, because it facilitated the effective combination of English vocabulary, conversations, and idioms for practical applications. Item I2 in Table 4 also received strong agreement, verifying that the recommendation learning module benefits learners in their learning processes. In other words, the active recommendation learning module of the PCAR system can efficiently enhance learner understanding and the ability to apply English learned through dialogues, essays, and vocabulary exercises. The feedback suggested that the module can also save

TABLE 3
Mean and SD of Experimental and Control Groups in Learning Willingness and Interest

# Question	Strong agree	Agree	No comment	Disagree	Strongly disagree
I1 Help to memory and foster to actually apply English knowledge in dairy lives.	22.6%	52.3%	21.1%	3%	1%
I2 To improve student's learning efficiency and help to strengthen your English application ability into daily life.	23.4%	49.6%	22%	5%	0%

TABLE 4
Mean and SD of Experimental and Control Groups in Learning Willingness and Interest

# Question	Strong agree	Agree	No comment	Disagree	Strongly disagree
I1 The context-aware module is helpful to scenario-learning of English.	28.2%	48.4%	19%	4.4%	0%
I2 The Recommendation module is helpful to provide suitable learning contents.	26%	48.3%	20.7%	4%	1%
I3 The whole learning functions is helpful to upgrade self-learning effect.	27.4%	47.7%	20.3%	4.6%	0%

considerable time spent searching for suitable learning materials and improve English application abilities in various daily life situations.

These results demonstrated that by using a proper filtering mechanism, the learning content in the PCAR system generally satisfied most of the learners' learning demands and suited their ability level. In addition, the learning functions facilitated self-learning because the system substantially reduced the search time and guided learners along suitable learning paths through context-aware and recommendation learning functions. Therefore, the learners' satisfaction with the learning functions of the PCAR system exceeded 75 percent , as shown in the response to I3 (Table 4). The results for the students who used self-fragmentary time to learn revealed that active learning increased more in the experimental group than in the control group.

5 Conclusion

This paper presents a novel context-aware recommendation learning mechanism that can provide appropriate English learning content to learners according to their location and environment through a 3G, 4G, or wireless local area network. Learners can access personal learning materials by using a smartphone or mobile device equipped with the PCAR system anytime and anywhere. The proposed mechanism was verified by the experimental results to benefit English learning. Among the learning modules, the multimedia learning subsystem, which can support personal learning behavior analysis, was combined with a context-aware subsystem to identify learners' environmental information and then determine the most appropriate learning content package for students in various environments; this was combined with learning through a learning recommendation subsystem, which was designed to support personalized learning suggestions and guidance. This learning approach produced beneficial effects, particularly for students who experienced difficulties in comprehending and applying English in daily life. The independent t test results indicate that the average posttest score of the experimental group was higher than that of the control group. Self-confidence in conversational ability and vocabulary knowledge when reading English essays was also higher in the experimental group than in the control group. Furthermore, the questionnaire responses indicated that the students in the experimental group exhibited more efficient and precise memorization, particularly for English vocabulary, phrases, and idioms, than did those in the control group. In addition, the experimental results and learning self-assessment of the students reveal that the *IPCAL* algorithm of the context-aware mechanism and active recommendation guiding learning were beneficial to most of the learners.

The PCAR m-learning system provides personalized learning content anytime and anywhere according to a learner's learning-log which records the learning behaviors of individual learners. Through the context-aware mechanism, this system can also recommend suitable English learning materials relevant to a learner's specific environment. This creates a ubiquitous and virtual English learning environment for learners to stimulate their interest for language learning; this enhanced interest was verified by the learners' responses to the survey questions. This study developed an intelligent learning platform for adjusting learning materials to suit different learners. This platform can also facilitate the self-learning of foreign languages by creating a virtual English learning environment.

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