Immersive Learning Environment with Integrated Interactive Video and Ubiquitous Technologies

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Abstract

Information technology is an integral part of daily life in many domains, including communication, computing, entertainment, and education. However, despite its pervasiveness, digitalization in various purposes and application in many human-based activities, it still plays the role of assisting and supporting people in manipulating and acquiring information. This study developed a ubiquitous learning environment based on the connection between digital and physical information. By using mobile learning technologies, including interactive video-based multimedia technology, GPS, GIS, and the electronic map service, learners can perform location-aware learning activities and experience corresponding appearances regarding a particular location. Accordingly learners can acquire new knowledge by participating in location-aware learning activities. We also demonstrate a ubiquitous learning activity of introducing the history of Tamkang University, Taiwan, and assess the effectiveness of the proposed ubiquitous learning environment.

Keywords*: Computer-assisted Instruction, Games and Infotainment, Pervasive Computing, Ubiquitous Computing*

1. Introduction

History education differs from education in other subjects. Students begin learning history at a very young age. Some concepts may be incorrect or nonexistent. Historical knowledge may be obtained from TV, historical novel, the old talks, radio and etc. Teachers must employ active learning methods to motivate students to think historically. As pointed out by Greene, S. [1] , "An important goal of teaching history is to enable students to acquire the habits of mind that characterize what it means to think historically." Yang, H-C. et al. [2] argued that history strengthens critical reading, communication, information processing and independent thinking skills. Yilmaz, K. [3] defined history as what happened in the past and each it represents much information such as the event, situation, people, geography information, technology development and culture. Thinking historically is the main objective of history learning. Thornton, S. J. [4] noted that historical knowledge motivates learners to construct critical meaning by encouraging students to inquiry the past, analyze with evidence and make reasonable inferences regarding historical events. Learning history requires the processing of

complex information. Yilmaz, K. [3] emphasized that students need to learn the historical methodology to realize and comprehend complex historical information. History makes students think historically by supporting them historical knowledge, inference procedure and synthesizes skill. Some teaching methods are useful to help students learning history and cultivate history thinking. Wains, S. I. & Mahmood, W. [5] stressed that a multi-perspective understanding history is the basis of historical thinking. Holt, T. [6] argued that introducing students to the raw materials of history is important cultivating the essential skills needed by a historian. It helped students to realize, question and make inference to the raw historical materials for who made it? What is the purpose of this document? Is there any evidence support our assumption? Schreiber, J. [7] found that students should use various artifacts (i.e. bowel, hunting tools) and historical document (i.e. first hand and second hand accounts, contract among races) to understanding and constructing the abstract history. Artifacts and documents can help students give students more comprehensive historical knowledge than that acquired from textbooks. Ellis, J. B. et al. [8] discovered that online interviews enhance history learning in children. The meta-cognitive process enhances students learning. Carroll et al. [9] believed that learning history is essential because it encourages meta-cognitive process. Also students can adjust their learning behavior after monitor their learning history. Researchers have proposed many new history education environments. For example, Lo J. et al. [10] applied GIS information to develop a web-based spatial-person-temporal history educational system called HES-SPATO (history educational system based on SPATO); SPATO means spatial, person, action/attribute, and temporal object. The participants in the experiments responded positively to this system. Chang W.C. et al. [11] integrated several ubiquitous technologies, including RFID, GPS location, and Google map in game-based learning. They attempted to construct a location-aware, digital game-based learning environment and to introduce the historical culture of Taiwan in the learning scenario. Wains et al. [5] designed a mobile multimedia game for education in the history of medieval Amsterdam. Users use UMTS/GPS phones for communicating and exchanging information when they explore the history of Amsterdam by walking in the city. The history game was played by 216 students in groups of four or five students. Storification roles include receiving (spectator), constructing (director) and participating in (actor) the story designed in the game. Observing the progress of E-Learning over the years clearly shows the rapid development of content and technologies. Kernel values of E-learning were created during this development process by constructing new learning style with new technologies such as network or multimedia. Meanwhile, some shifts in traditional pedagogic theories have occurred to explain changes in learning style. Game-based learning is one example. Research in computer games as an academic discipline first started in the year 2000. Computer games were initially considered learning absorbency killers with no cognitive value. However, from 2004 and onwards, academic research in games integrating e-learning has shifted to Game-based Learning. Based on the previous work and related work, this study implemented Game-based Learning within Ubiquitous Computing. A ubiquitous computing system requires integration of computing nodes with the physical world. Depending on the circumstances, communicating components can change both identity and functionality over time for social implication and evaluation. Thus, we, designed problem-solving games can help students to solve problems in the real world. System is able to sense the learner situation in the real world and record the real world information of the learner. By recording these learner behaviors, the games provide personalized information or services to the learners based on real-world contexts.

The organization of this paper is as follows. Section 2 introduces related technique issues. In Section 3, architecture and implementation of the architecture are described. Section 4 presents a Case Study and several methods of supporting ubiquitous learning. Section 5 presents the experimental results, and Section 6 analyzes the results. Section 7 concludes the work.

2. Related Work

Advanced information technologies can now help people improve their quality of life, especially in education and entertainment domain. Lou, Y., et al [12] stated that video is one potential medium for delivering useful information with sound, video and text form to the

people. Liao, W., et al [13] introduced that Interactive Video-on-demand (IVoD) service enables two-way interaction and direction controlling instructions with video streaming with segment data by using the cooperating with both Set-Top Box device and advanced network technologies. The VoD framework was first presented in Wong, J. W. [14], and Fahmi, H. et. al. [15] later proposed an IVoD service and video segment streaming processing framework. Daily life applications of interactive video have increased. Even in education domain. Cheryl, H. et al. [16] found that learners have positive perceptions of interactive video technology. Zhang, D. et. al. [17] also found that using interactive video materials for e-learning can improve learning efficiency. Additionally, advanced mobile technologies enabled Chang, H. B. et al. [18] to apply interactive video technologies to on-campus mobile learning activities. These developments show that interaction in interactive video systems is a major consideration. Champion, E. [19] and Muda Z.et al. [20] indicated that designing meaningful interactions is extremely difficult without expert assistance. Bing, J. et al. [21] demonstrated complex user interactions involving PDA, smart phone and tablet. The many applications of interactive video systems include education, commerce, sports and entertainments as Zhang, L. J. et al. [22] showed. Augustin, I. et al. [23] indicated that advanced Handheld PCs and wireless networks provide more convenient applications in business and entertainment domains. Even in education domain, Wains, S. I. et al. [5] proposed the concept of integrating mobile learning with e-learning to accommodate different learning styles.

Advancing GPS technology now enables the possibility of combining the above technologies to provide adaptive useful content within a particular location area [23][24]. This technology also enables data collection specifically for mobile device users [25]. Therefore, the above technologies have increased interest in Ubiquitous Learning [26][27] in the education domain. Jorge Barbosa et al. [28] proposed a combination of mobile and ubiquitous computing technology to deliver a Computer Engineering course with Undergraduate Course of Reference (GRefe) specifications that included course design rules for Learning Programs and Learning Projects. The study provided a detailed description of related Ubiquitous technologies and course design methodologies used to implement practical ubiquitous learning course content and learning activities. Researchers have also begun to explore the combination of mobile game-based learning environments and location-aware information. For example, Spikol, D. & Milrad, M. [29] had integrated the traditional Geocaching game in Sweden and related mobile technologies to develop the outdoor learning game system. One possible application is map navigation and interactive learning materials in order to develop an outdoor learning system that enhances learner motivation when participating in outdoor learning activities. Bichard, J-P. & Waern, A. [30] proposed a cooperative outdoor experience learning game system that integrates AR, GPS technologies and real actors to provide the immersive outdoor gameplay experience. Young, S. S-C. et al. Young, S. S-C. & Liang, C-H. [31] proposed the Across Mobile Platform Learning System (AMPLe) for outdoor learning activities for elementary school learners. This system could deliver learning courses to learners by wireless communications with mobile devices.

Recent studies confirm that games have some advantages to attract and help learners to enjoy their learning activities. Prensky, M. [32] pointed out that the applications which like the computer game, email, mobile phone and peer-to-peer communications are essential in daily life. Therefore, we should provide vary kinds of learning strategies such as Problem-Based Learning, Situated Learning or Game-Based Learning in order to fit learner needs. Among those learning strategies, the Game-Based Learning not only provides the immersive learning style, but also improves the learning efficiency. Clark, C. D. [33] pointed out that learners could do the learning behavior by learning objective delivery, problems analysis and overcome problems in order to complete the learning missions. Merill et al. [34] pointed out that game has some important elements to improve gamers' game play motivations by mission challenging and immediate game rewards. Owen [35] stated that most humans' learning behavior could be presented by game play style. He proposed six contentions that describe game elements: "game aims", "game location", "game pieces/players", "the means of making progress in the game", "game language" and "time frames of games". He also introduced the conceptual architecture to construct the practical game-base learning environment. Many studies report positive outcomes

of game-based learning. In terms of learning efficiency, for example, McFarlane et al. [36] demonstrated that game-based learning can improve performance in geometry students. Lou, Y. et al. [12] showed that game-based learning also improves learning attitude and learning efficiency. In learning recognizing ability part, Fitzgerald, G. [37] and Jenkins, H. [38] pointed out that learners have control force on doing learning game activities. It could cater to different learners' learning behavior in order to improve their learning motivation and learning efficiency. In learning motivation part, McFarlane et al. [36] and Jenkins, H. [38] showed that game-based learning maintains the attention of learners and increases the time spent on learning activities. The above literature indicates that game-based learning has many positive advantages that should be considered when designing interesting and the useful learning course content and learning activities to attract learners' learning attention when doing their learning course but to improve their learning results.

3. Uv-GBL Architecture and Implementation

3.1. Uv-GBL System Architecture

Developers targeting the Ubiquitous Video Game-Based Learning environment must carefully consider the system architecture for supporting traditional desktops and modern mobile learning. The modern mobile learning platform could be a laptop or a UMPC (Ultra Mobile PC). The three main components required by the system architecture are ubiquitous interactive video learning content, the ubiquitous learning client, and most importantly, the backend game-based learning server. Figure 1. illustrates the interrelationships in the proposed system architecture.
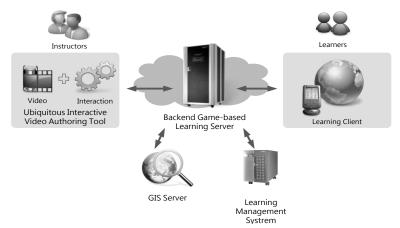

Figure 1. The Uv-GBL System Architecture

The ubiquitous interactive video learning content can motivate, attract, and interact with students, which may not be possible in conventional learning contexts. Learners can perform location-aware learning activities by using ubiquitous interactive video learning content with various learning paths and strategies. To create interactive video learning content, this study proposes an interactive video course authoring tool. Instructors can use the authoring tool to design the interaction mode and to assign various learning tasks in each learning unit. After generating the video courses, instructors can upload them to the backend game-based learning server and assign them to the registered learners.

In a ubiquitous learning environment, the learning client consists of the learners and the mobile learning devices. The main concern of the learning client is the presentation of ubiquitous learning content and the way of learning activities performed. Typically, the learning client should be easily augmented with other devices, such as GPS (Global Positioning System) or RFID (Radio Frequency Identification) to support the location-aware learning activities. The

ubiquitous learning platform employed in this experiment was the EeePc manufactured by ASUSTek Computer Inc.

The backend game-based learning server includes the following components:

- Learning Management System for managing the learning content, the learning activities, and the learning behavior.
- Gaming Server for maintaining the interrelationship of each interaction in the video courses, and deliver the corresponding quiz to the learners as a to-be-solved mission.
- GIS Server for providing location-aware information bounded to the interactive video courses for achieving the ubiquity.

After connecting to the backend game-based learning server, the learning management system can deliver applicable interactive video learning content to the learning client, and the corresponding services, such as the GIS (Geographic Information System) service and the gaming service, are triggered to function and maintain the subsequent learning activities. From a functionality perspective, the services of the ubiquitous learning environment can be classified by functionality. Related modules and workflow in the proposed Uv-GBL system are introduced in the next section.

3.2. The Uv-GBL System Modules – Server Side

This section describes the Uv-GBL Management Server modules. Figure 2. shows the Uv-GBL Management Server modules. The Client Request Handle Module manages all programs/processes requests and connections from client side. In Identity Checking Module, instructors and learners utilize a Member information table to store related member data. The table could record all basic properties and related operating process from instructors/learners. The action log stores the particular course ID or series course ID for the instructors/learners. In Uv-GBL course content design part, the content is divided into course content and game mission content. Instructors can develop the course content by using the Uv-GBL Course Content Authoring Module, Course Management Module and Game Mission Management Module. All existing game missions in the repository can be used individually or shared with other instructors when designing the game mission scenario. This approach reduces the load on instructors when constructing other game scenarios.
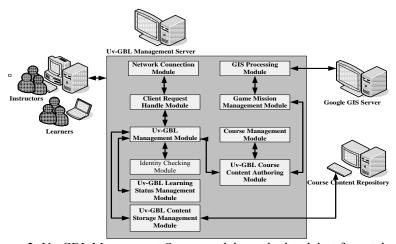

Figure 2. Uv-GBL Management Server modules and related data format design

In the game mission data format design phase, the question and test data table may store the request properties of particular information of mission. The data include related mission description, questions and corresponding answers. This data management function is performed by the Uv-GBL Content Storage Management Module. The Uv-GBL Learning Status Management Module processes and records data related to learning progress. Instructors and learners could use related functionalities to review or to analysis the efficiency after completing

the related learning progress. The Uv-GBL Management Module coordinates and manages central information data.

3.3. The Uv-GBL System Modules – Client Side

The Uv-GBL Client includes several modules for various purposes. This section describes the functionalities of these modules. The Message Request Handle Module manages all programs/processes requests and connections on the server side. When learners begin the Uv-GBL learning activity, they must first download the Uv-GBL course content package. The Uv-GBL Content Packaging Module controls the content packaging/un-packaging. The Uv-GBL Game Play Management Module and the Game Map Processing Module provide the initial game environment according to the un-packaging Uv-GBL course content and cooperates with Uv-GBL Learning Status Management Module to monitor and collect the current learning status data.

Figure 3. and 4. show the Uv-GBL game play interface. The designed map guides users to specified locations to find clues and then solve missions. Target locations, success/failed locations and current location of learner are displayed in the map. Learners can use the UMPC, which cooperates with GPS/GIS functionalities to ensure the right gaming route. When learners reach a certain stage, they can ask the NPC (Non-player character) to begin the game mission solving stage. After the players complete all missions, the related game play status data is sent to the Uv-GBL server. The players can then view the game results by using the game result listing menu.
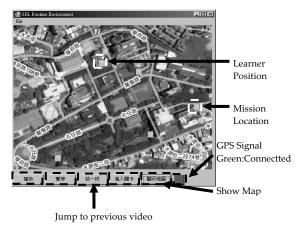

Figure 3. The Uv-GBL game play interface

Figure 4. The Uv-GBL game interactive video interface

3.4. The Uv-GBL Course Content Authoring Tool

This section introduces the functionalities of the Uv-GBL Course Content Authoring Tool, which the instructor uses to generate course content, game scenario and related game parameters setting through web browser. The tool has two sub-tools, a course content authoring tool and a game scenario authoring tool. The course content authoring tool (see Figure 5., section A) can help the instructor develop the main course content with game style in interactive video form. The game scenario authoring tool aims to provide the functionalities for interactive video editing and course content attribute setting (see Figure 5., section B and C) for the experience game scenarios. The instructor can edit the learning sequence and add the learning content as game scenario map style. The Uv-GBL course content authoring tool is developed in C# programming language to enable complex interactive game elements and related help functionalities. In Uv-GBL game scenario authoring tool developing part, the AJAX-based (Asynchronous JavaScript And XML) technologies are used to design the operation interface.

Figure 5. shows the game scenario authoring tool, course content authoring and related tool interface.

Figure 5. The Uv-GBL Course Content Authoring Tool Interface

4. Case Study and Numerous Methods for Supporting Ubiquitous Video Game-Based Learning

To evaluate the functionality and usability of the interface system, this study uses the usability testing method- user testing. Effectiveness, efficiency, and user satisfaction are assessed in order to identify usability problems.

4.1. Participants

Thirty participants were recruited from the Tamkang University student population. Participants who agreed to participate received small gifts. Eight graduate students and twenty-two undergraduate students who met selection criteria such as computer literacy and experience playing computer games were enrolled in the study.

4.2. Procedure

Before the experiment, each participant provided basic information by completing a questionnaire. The basic information included age, frequency of computer use, and experience playing computer games. Each participant was then received instruction regarding the game system and rules. After the end of the instruction, we took participants to unsheltered place and set up the GPS system. When the material for the ubiquitous video game-based learning environment was working, each participant could start their adventure game. The game required the completion of five tasks to be performed on the Tamkang University campus. Time limited of 50 minutes, when time was over, each participant must return to in-situ, regardless of success or failure. Finally, each participant had come back; they were required to fill out two part questionnaires about the learning satisfaction and the workload.

4.3. Apparatus

4.3.1. "Morae"

The two functions of the "Morae" are to record user behavior, expressions, and voice and to then analyze the recorded information by counting the rate of task completion, time to complete a task, or numbers of appeared errors.

4.3.2. Evaluation Criteria

Overall user interface quality was assessed in terms of the effectiveness, efficiency, and user satisfaction. The effectiveness was measured by percentage of tasks completed. Efficiency was measured by time to complete task and numbers of errors. User satisfaction was measured by questionnaire.

4.3.3. Task Scenario

Each of the five tasks in the adventure game required participants to reach a specific position and then press the "Entry barriers" button. The system then showed the video about the specific position. After viewing the video, the participants were required to answer questions using the interactive video technology to complete the task. Task completion was indicated by the check mark on the campus map.

4.3.4. Satisfaction Questionnaires

The four parts of the satisfaction questionnaires were overall evaluation, operational level, game level, and content level. The overall evaluation assessed game playability from multimedia (e.g., "I feel comfortable with the screen of the game"); the remaining four questions allowed participant to comment on usability of the interface control (e.g., "I think it's easy to learn about the game of the interface control"); the game level (e.g., "I think there are many challenges in the game"); and the content level (e.g., "I think the storyline is specific and clear in the game"). Each part included two to three questions.

5. Experiment Results

Quantitative (e.g., effectiveness, efficiency, and user satisfaction) data were obtained by the user experiment. The "Morae recorder" was used to record user behavior (e.g. numbers of mouse clicks, numbers of errors, or time of completed task), expression, and voice. The "Morae manager" was then used to analyze user behaviors and user observations.

5.1. Effectiveness - Rate of Task Success

The percentage of tasks completed was calculated by "Morae". Completed tasks received 0 points; completed difficult tasks received 1 point; unfinished tasks received 2 points. As Figure 6. shows, the average scores for completion of tasks 1-5 were 0.41; 47; 0.26; 0.33; and 0.37, respectively. By participants, the average task scores is 0.3; there are 7 participants over the average.
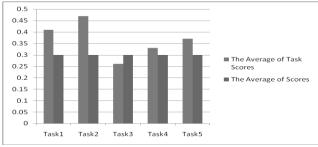

Figure 6. Experiment Results in "The Average Task Scores"

5.2. Efficiency

5.2.1. ″Morae"

As Figure 7. shows that the average task completion time was 800 sec (task1= 940 sec; task2= 785.23 sec; task3= 685.32 sec; task4= 797.91 sec; task5= 796.35 sec). Eight of the participants exceeded the average.
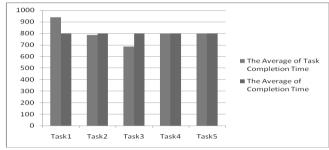

Figure 7. Experiment Results in "The Average of Task Completion Time"

5.2.2. Evaluation Criteria

Participants completed most tasks with some errors. As Figure 8. shows, the average number of errors was 0.51(task1= 0.74; task2= 0.44; task3= 0.56; task4= 0.33; task5= 0.52). Seven subjects exceeded the average. And it should be noticed about the average of 4 participants is higher than others.
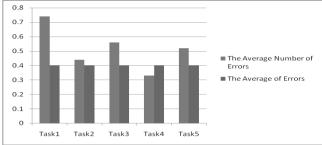

Figure 8. Experiment Results in "The Average Number of Errors"

5.3. User Satisfaction

User satisfaction was measured on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). The average user satisfaction score was 3.708046, which was higher than expected. However, this score was still within an acceptable range. Most players indicated that the game was not challenging. The players also indicated that the operation of the game system was unstable. However, all subjects indicated that they enjoyed the learning method.

6. Experiment Discussion

6.1. Effectiveness

The experimental results showed that the rate of successful task completion was very high. All participants were able to finish their tasks on time. Importantly, however, seven participants exceeded the average task completion time. We deduce that the causes were the limitations of GPS and system error. The GPS was unstable because it requires open, and some buildings or

shelter may have interfered with the GPS signal. If the GPS cannot trace the location of the participant, the system cannot function. Second, the equipment limitations sometimes cause system failures. A manual should be developed to help users prevent system failures. Participants who encounter system errors were usually unable to accomplish their tasks.

6.2. Efficiency

Average task completion time did not significantly differ. Overall, participants usually accomplished their tasks on time. A commonly observed phenomenon was that completion time for the first task exceeded that for other tasks. The reason was that participants needed time to become familiar with the system. The phenomenon is associated with the number of errors. When users were unfamiliar with the system, they always tried different operating modes (e.g., pressing different buttons, clicking mouse, or doing nothing).

6.3. User Satisfaction

Most participants enjoyed this learning method and found it enjoyable and interesting. They also found it to be an effective learning method. However, user feedback indicated that the mini notebooks were too heavy to carry when walking. Users also advised using PDAs instead of mini notebook. Therefore, the choice of the mobile learning device is another important consideration.

7. Conclusion

This study developed a ubiquitous learning environment by using mobile learning technologies. The aim was to facilitate location-aware learning activities by applying GPS information, interactive video learning content and the electronic map service. Learners could thus seamlessly feel and experience the subjects based on the connection between digital and physical information. To test whether the system objectives were achieved, a location-aware learning activity introduced the history of Tamkang University, Taiwan in the proposed ubiquitous learning environment. The experimental result showed that, not only are learning performance and learning impact significantly increased in the ubiquitous learning environment, but also that the learning content are more enriching and attractive when digital and physical information are combined.

The proposed ubiquitous learning environment aims to facilitate location-aware learning activities so that learners can experience and reveal the learning context in the surroundings. Learners can also arrange the learning sequence themselves and select interested topics on demand in the location-aware learning activity. Hence, the sense of personal responsibility and self regulation are also improved. The learning environment in the new generation can benefit from augmentation with advanced information technologies. It is also an essential and considerable topic, which continues to be an important topic in innovative learning research.

8. Acknowledgment

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