The Pervasive Learning Platform of a Shanghai Online College -- a Large-Scale Test-bed for Hybrid Learning

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Abstract. The rapid evolution of Information and Communication Technologies has led to new ways of learning and education. In Shanghai, researchers and developers of an online college actively seek technological interventions to provide first-class e-learning services for about 17,000 enrolled students. They developed a cutting-edge pervasive learning platform that provide "always on" education. It aims to support "Learning Anytime, Anywhere", which is accomplished through extending the real classrooms and also supporting web-based self-paced learning. The platform is composed of three components: a) distributed Standard Natural Classrooms, the smart spaces to provide natural interaction for teachers and students; b} large-scale media streaming for multi-mode terminals delivering fully interactive lectures to PCs and mobile devices; c) dynamic and personalized web-based learning systems. Multi-modal interactions are supported that students learning on this platform change from passive learners to truly engaged learners who are behaviorally, intellectually, and emotionally involved in their learning activities.

Keywords: e-Learning, pervasive learning, hybrid learning, learning platform

1. Introduction

The rapid evolution of Information and Communication Technologies (ICT) has led to new ways of learning and education. e-Learning systems have been promoted by most education institutions and numerous corporations to facilitate a better learning and teaching environment. Products such as Virtual-U [3], WebCT[17] and Blackboard [2] have been in use for the past few years. These systems have implemented a number of fundamental components such as synchronous and asynchronous teaching systems, course-content delivery tools, polling and quiz modules, virtual workspaces for sharing resources, whiteboards, grade reporting systems, and assignment submission components. Many online colleges such as the UK Open University[7], the Hong Kong Open University[8] and the Network Education College of Shanghai Jiao Tong University (SJTU)[6], have developed and deployed their own e-Learning platform and infrastructure to provide adaptive and efficient e-Learning services. Today, eLearning becomes heavily learner-centered, emphasizing pervasive and personalized learning technologies[13]. As both the traditional classroom learning and web-based learning offer strengths and suffer from limitations, it is now a trend for e-Leanring systems to combine the strengths of the two into hybrid learning [5].

In china, more than half of the right age students are not admitted to higher education institutions every year. The data from the Ministry of Education press Sept 2007 showed that 77% of the right age youngsters (about 19 million) were not able to take higher education. From 2001, Chinese government began to authorize colleges and universities to establish online colleges to boost occupational and adult education and to ensure more access to higher education. Online colleges usually have large numbers of distributed students in one class, so it is not feasible for traditional classroom lecturing. Many online colleges use the hybrid mode of delivering lecture CDs and web-based asynchronous learning. But the main problems there are the lack of learning-inducing stress for learners and the resulting high non-completion-rate. The traditional instructor-led classroom learning is proven to be an effective and successful education method which is fresh, original, interactive and on-the-spot. We have conducted a survey among 5000 online college students which shows that only 280 students prefer to learn traditionally web-based courses while most students select real-time learning.

Researchers in the SJTU online college have been holding the vision that the most import thing is to provide live and interactive lectures to the distributed students. Great efforts have been made by the researchers and developers of the college to leverage existing and emerging ICT to augment the function of traditional classroom and then digitalize them, and finally deliver them to diverse devices. In addition to the synchronous live lecturing, asynchronous web-based learning is also provided, allowing students to study according to their needs and preferences. Learners appear to enjoy this flexible, student-centered approach. Within seven years (2001-2007), this College's enrollment has grown from 120 students to 17,000 students.

This paper presents a pervasive learning platform which is developed and used at the SJTU online college, where we are motivated to research on exploiting new and emerging ICT to provide effective learning services for students. This online college currently has about 17000 enrolled students which make the platform a large-scale test-bed for hybrid learning. We will start by outlining the pervasive learning platform (Section 2). Then we describe three main components of the platform in section 3~5 respectively. Finally conclusion is made in section 6.

2. The Shanghai Pervasive Learning Platform

The e-Learning system developed at the SJTU online college is kind of pervasive learning platform that provide "always on" education[13]. It aims to provide "Learning anytime, anywhere", which is accomplished through extending the real classrooms and also supporting web-based self-paced learning. It differs from the previous platforms by the feature of heavily learner-centered, and by using wireless computing and pervasive computing technologies.

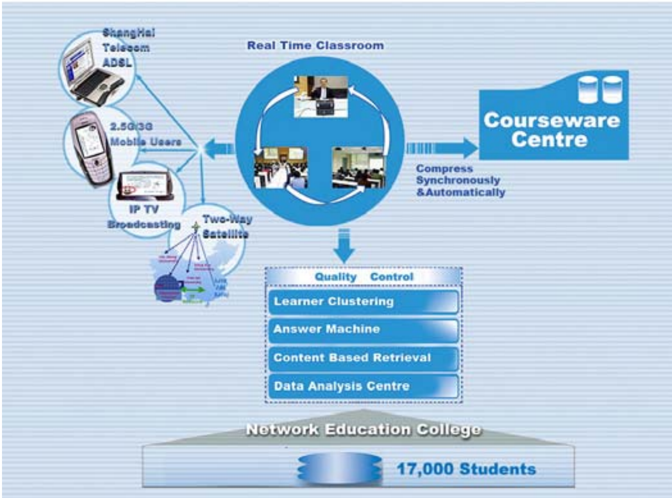

Fig. 1. The Shanghai Pervasive eLearning Platform

Figure 1 gives the architecture of the platform. It is composed of three main parts: a) distributed Standard Natural Classrooms (SNC), the smart spaces to provide natural human-machine interaction and context-aware services for teachers and students; b) large-scale media streaming for multi-mode terminals delivering fully interactive lectures to PCs, laptops, PDA, IPTV and mobile phones through heterogeneous networks; c) dynamic and personalized web-based learning providing multiple services for learning management and quality control, such as dynamic learning services, collaborative learning communities and personalized recommendations. The core of the platform is interconnected SNCs distributed around Shanghai, the Yangtze River delta, and even in remote western regions of China such as Tibet, Yan'an, Xing Jiang and Nin Xia. They are equipped with numerous smart devices/sensors and specially developed software. The live interactive lectures are digitalized and then delivered to PCs, laptops, PDA, IPTV and mobile phones through various networks such as Shanghai Telecom ADSL, GPRS, IPTV, two-way satellite and the Internet. A recording program records all the media components including audio, video, handwriting and files shown on the computer into coursewares. Students can tune into these recordings live online, or they can download them later for review. The web-based learning services consist of the content based retrieval search engine which enables the students to find their desired materials conveniently and quickly, the answer machine which responds to students' questions automatically, the data analyze center and self-organized learning community which analyze students learning patterns and provide personalized services, and other learning tools such as assignment system and examination system.

Chinese classrooms, whether on school grounds or online, have long suffered from a lack of interactivity. Researchers and developers of this platform actively seek technologic interventions that could greatly increase interactivity in large blended classroom. The platform support real-time multi-modal interactions such as audio, video, text, short message and pen-based etc. In conclusion, this platform has five distinctive characteristics: broadband, wireless, real-time, interactive and multimedia. These five factors integrate together and supplement each other, servicing the whole e-Learning framework.

3. The Standard Natural Classrooms – the Headwaters for Learning

Being the most popular way for off-campus education in China, many real-time e-Learning systems deliver live lectures through satellite in a way like Television University or using commercial video conference systems. Most of these systems are desktop based that the teacher must remain at the computer, using the keyboard and mouse to manage the lecture, which not only have deficiencies in interaction, scalability, mobility and maintenance but also loss the effectiveness of classroom education to a large extent. Many efforts have been made to bridge the gap between real-time remote classroom and traditional classroom activities such as the Smart Classroom project in Tsinghua University[12].

By applying pervasive technologies in real classrooms, we developed numerous distributed Standard Natural Classrooms both in Shanghai area and across the whole China. These SNCs are equipped with high-tech devices, tools and software infrastructure that all the SNCs are configured in a unified STANDARD way. In SNCs, teachers can move freely, use multiple NATURAL modalities to give the lecture and interact with remote students in the same way as the traditional classrooms. All these SNCs are distributed around Shanghai, the Yangtze River delta, and even in remote western regions of China such as Tibet, Yan’an, Xing Jiang and Nin Xia. They are interconnected either through the broadband IP network or through two-way satellites. During a lecture, students could select to attend the class in the primary SNC with lecturers, in the nearest remote SNC or even in their own home. Figure 2 is the classroom setup of a typical SNC in use at the online college. The smart board and lecture notes touch screen display presentations (e.g. PowerPoint), while also act as a whiteboard for handwriting. The instructor can write on materials on the touch screen with a pen or on the projected whiteboard with a laser E-pen. To optimize the video quality, a pan-camera could track the instructor when he/she moves around in the classroom, which actually is installed at the rear end of the SNC. Another monitor camera is mounted in the front of the classroom and it captures students’ attention status by recognizing their face expressions. The feedback screen supports the real-time multi-modal interaction and displays the questions and poll results based on which the teachers could fine tune their lecturing in a positively way. Other devices are provided and installed to collect the context information and to control the classroom equipment, for example RFID (Radio Frequency IDentifier) tags are used to identify and track students and context-aware light controller to switch on/off the light intelligently. Using this hi-tech environment, the teacher can move freely, demonstrate his body language, and interact with learners as naturally and easily as in a traditional face-to-face classroom.

The SNC involves a number of component technologies that make the interaction between the teacher and remote students as natural as that in a physical classroom. Due to space limitations, we only describe three of them and how these technologies function in the SNC.

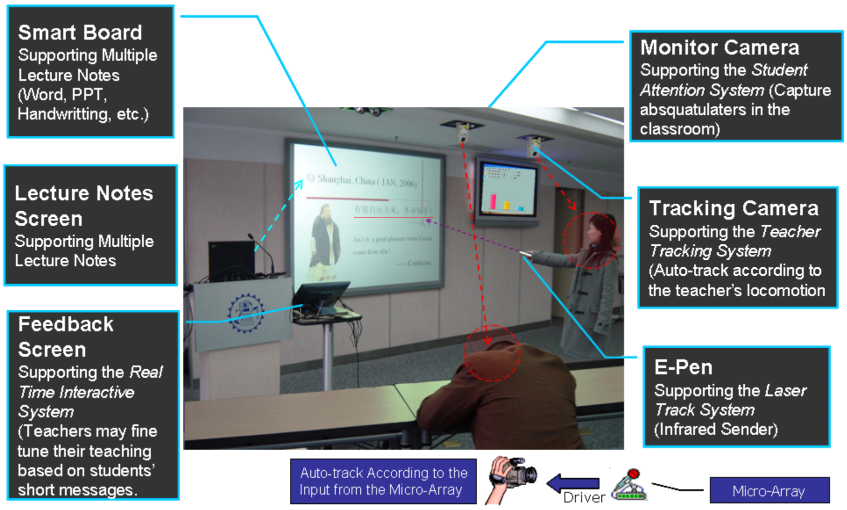

Fig. 2. The typical SNC setup

3.1 Multi-modal Natural Interaction

In this part, the phrase "interaction" refers to both human computer interaction and teacher student interaction. Technologies are leveraged to support multi-modal interactions in SNC, that at one side, students and teachers could communicate and interact as naturally as the face-to-face education, and at the other side, teachers could teach in a usual way through handwriting, audio command and laser pen, thus eliminating the limit of desk based interaction in traditional tele-education systems. As the data collected from this platform reported, interactions could much better engage students in the learning process and students changed from passive learners to truly engaged learners who are behaviorally, intellectually, and emotionally involved in their learning tasks[16].

The interaction modes involve video, audio, text and pen-based handwriting. During lecture, the live classroom scenes are transmitted to remote SNCs and displayed on wall-mounted large screens, at the meantime, the remote SNC video are also sent back to the lectures' SNC. For learners using PC at home and mobile devices on the way, the live teacher's video is delivered together with the audio and lecture notes. When a teacher talks with a specific student, this student's video will also be transmitted to all the other SNCs. The teacher could use voice-commands to perform some common tasks such as "next slide" or "go back to the last one". Meanwhile, students can send text messages to the instructor through cell phone Short Message Service or the text window of the SNC system. Students' messages will be displayed on the instructor's feedback screen, to inform the instructor their learning progress, questions, or any other feedback, that the instructor could respond in a positive way.

Teachers in real classrooms often write on chalkboards or whiteboards. Most current tele-educations, however, confine teachers to their computers by requiring them to use the mouse and keyboard. We address this problem by allowing the teachers to write on the touch screen with a touch pen. With the help of this pen, teachers could write on their prepared lecture notes in the same way as writing on a sheet. There are advantages of pen-based handwriting over the traditional chalk. The touch pen could write directly on the lecture notes, no need to re-write to the chalkboards which could improve the efficiency greatly. And the erasure job is easier and healthier with a digital eraser or just opening a new page. The remote students could see the same lecture notes and handwriting on the smart board as local students do. A remote student who has a PC or mobile devices could also write on this board freely—for instance, a student might write the solution to a question the teacher has just posed. This kind of pen-based interaction is very important for some science courses such as Math and Physics. When teachers leave the touch screen, for example, walking into the students or holding a model, they could even use a laser pointer to write on the projected smart board. A computer-vision-based module turns an ordinary laser pointer into an E-pen.

3.2 Movement Tracking and Intelligent Focusing

In a conventional classroom, students naturally follow the class's focus as it changes from time to time. For instance, when the teacher writing on the electronic whiteboard, the focusing should be the content of handwriting; when the teacher answering questions, the focusing might be his gesture and expression; when a teacher holds up a model, the model becomes the object of general interest. Yet in most current tele-education systems, remote students only see a fixed scene regardless of the changing context of the class, which hampers their understanding of the instruction. Although a human camera operator can select the proper view for live video, the high labor cost often makes this infeasible.

The intelligent focusing module we developed overcomes this problem. This module consists of a pan-camera and a decision module. By drawing clues from the classroom context, the intelligent focusing module automatically distinguishes among several activities during a typical class. Using this information, the decision module selects the most appropriate view and control the pan-camera to focus on the proper on-spot object. In SNC, instructors could move arbitrarily. Movement tracking module is implemented and used to focus on the moving instructor's video. The movement tracking module employs face detection technology and RFID localizer system.

3.3 Emotion Detection and Affective Learning

Researches have demonstrated that emotion is an important factor in learning and that the human brain is not just a purely cognitive information processing system, but also a system in which both affective functions and cognitive functions are inextricably integrated with one another[4]. Of course nobody denies the role of 'affect' or emotion in learning. Teachers know that it plays a crucial role in motivation, interest, and attention. But in most current e-Learning systems, there has been a bias towards the cognitive and relative neglect of the affective[9]. We conducted a primary study on affective learning model and built a prototype to detect emotions from physiological signals. The goal is to help improve students' learning experience by adapting existing e-Learning systems based on the learner's emotional state.

The physiological data for emotion detection were collected from three bio-sensors: a skin conductance (SC) sensor measuring electrodermal activity, a photoplethysmyograph measuring blood volume pressure (BVP), and a pre-amplified electroencephalograph sensor measuring EEG activity from the brain. We have achieved a best-case accuracy (86.5%) for four types of learning emotions[11]. And we have built two prototypes to make use of the sensed emotions. One is emotion-aware SNC. Expert teachers are able to recognize the emotional state of their students and respond in ways that positively impact on learning. But in the e-Learning case, there are large numbers of remote students in distributed classrooms and mobile users. We provided a solution for such problems via the incorporation of students' emotional information into the pervasive eLearning platform. Firstly we simply feedback the students emotions back to the lecturer in real-time, that the lecturer would adapt the lecture style, speed and content based on the students' emotional statistics. And then we are collecting data to investigate the computational model of emotion-aware group interaction dynamics so as to enhance the information flow within the group by smoothing the emotion flow. Another one is emotion-aware adaptive content delivery. Based on our previous work[10], we built a prototype to provide personalized service based on the learner's emotions.

4. Large Scale Media Streaming for Multi-terminals – Channels in All Directions for Learning

The aim of pervasive learning is to provide end users the ability to access education resources using any available network devices anytime anywhere. Our platform supports three types of multimedia access: tuning into live lecture broadcast, Lecture-on-demand (LOD), and downloading archived lectures. The challenges here are, at one side the adaptation of education content based on the current context such as the device computing capacity, screen size and network bandwidth; and at the other side to provide efficient reliable media transmission mechanism even for large scale concurrent user accessing. We now introduce two cases to manage these issues.

4.1 Hybrid Multicast Model for Media Streaming

Currently, the typical media streaming e-Learning systems are one-to-many (lecturing) or many-to-many (interaction and collaboration) interaction modes. So using multicasting for learning content transmission can dramatically improve the quality of service and network bandwidth efficiency. Multicast can be either performed in Internet Protocol (IP) layer or application layer. IP multicast has the advantage of efficiency, but the critical requirements of routers ,scalable inter-domain routing protocol and robust congestion control mechanism make it difficult to be implemented on heterogeneous inter-networks such as CERNET, telecom ADSL, dial-up network as well as mobile network. Application layer multicast is based on a high-level virtual network leveraging unicast to perform multicast by data replication. As there is no need for supporting from routers, flexible congestion control mechanism could be used to ensure the quality of data transmission. In recent years, application layer multicast (ALM) has gained more and more attention among researchers. In the pervasive learning environment, users might be either in a remote classroom, at home or on the way learning with mobile devices. And users are distributed in a heterogeneous sparse-aggregation way. Therefore, we designed and implemented a hybrid multicast model that combine ALM and IP multicast. The network topology is tree-like architecture. Data is distributed in two ways: one is tunnel distribution which is based on UDP unicast at the application layer across different multicast domains; the other is IP multicast within a multicast domain.

As there is a lack of necessary QoS control mechanism in current IP network and the variety of end devices and network conditions, distribution of media data suffers due to limited bandwidth, delay and package loss rate, so there is an urgent need to provide QoS control mechanisms to ensure all these steams to be distributed according to their priorities to different devices. Our strategy is to periodically probe the network variables such as bandwidth, delay, package loss rate etc, and adapt the multicast routing algorithm based on measurement of these network metrics.

4.2 Content Adaption and Interaction Patterns for Mobile Learning

When tuning into the live class, students presently have four options: 1) presentation, audio, and a small video of the real-time classroom, 2) video (including audio) of the instructor only, 3) enlarged display of the presentation shown at that time, and 4) a close-up display of the instructor’s facial expressions and their body language. Our recent survey shows that 85% of the students prefer option 1. In theory, the presentation, audio, and video mode can create a better context for learning. That is, the feeling of being in a real classroom with the instructor and many other students nearby. Catering to this need, three types of streams are provided for mobile users: a) an instructor’s presentation screen from his desktop b) the instructor’s facial expressions from a video camera, and c) the audio stream of an instructor’s voices from a microphone. For mobile phones to retrieve these learning contents, they have to get access to the Internet by GPRS (General Packet Radio Service). Whereas the bandwidth of GPRS is quite limited, which are approximately 28.8kbps for downloading and 10kbps for uploading, to successfully deliver the learning contents to mobile phones, they are further compressed. Each of the three streams are reduced to as low as 8kbps, so that it can better adapt to the bandwidth of GPRS. Figure 3 shows the course display on the mobile phone Nokia 6600. Based on the GPRS network conditions and the students' preferences, the transmission and rendering pattern could be customized, for example, close the video or presentation function.

Fig. 3. Course display on the mobile phone Nokia 6600

The mobile learning system not only delivers learning materials and live classrooms to mobile devices, but also encourages interactions in large blended classrooms. Once a student's mobile phone connects to a class, the instructor periodically receives a screenshot of the student's mobile device so that the instructor can monitor the student's progress. Meanwhile, students can send text messages to the instructor through cell phone Short Message Service. To address these messages, the instructor can give oral explanations or can reply through short text-messages. Students can also participate in polls and class activities which are often related to the various aspects of course conduct, content, pace, clarity, structure etc. The poll results are immediately sent back to the instructors so that they could adjust or improve the instruction accordingly. In addition, audio interaction could be initiated when necessary. This could help alleviate the problem of slow typing on a mobile phone. Language classes, especially, would benefit from an audio enhancement enabling listening and speaking practice under the teacher's guidance.

5. Dynamic and Personalized Web-Based Learning Services – the Quality Control of Learning

The web-based learning services is a platform students could conduct asynchronous self-paced learning anytime anywhere. It is comprised of the content based retrieval search engine which enables the students to find their desired materials conveniently and quickly, the answer machine which responds to students' questions automatically, the data analyze center and self-organized learning community which analyze students learning patterns and provide personalized services, and other learning tools such as assignment system and examination system. In this section, we introduce two existing distinctive services and one innovative web2.0-based service as the dynamic and personalized learning service examples.

5.1 Answer Machine, the Intelligent Q&A System

Because of the large number of the students in online teaching, a lot of teaching tasks have to be supported by the computer. Let's take Answer Machine[15], the Question and Answer system as an example. If there are 200 students online and each student asks only one question, then it will take a teacher several hours to answer all these questions. From our experience, many questions usually have the same or similar meanings. The solution to this problem is to share the answers among the students and let a computer recognize similar questions and answer them automatically. If the computer cannot find an answer, it transfers the question to a teacher. After the teacher answers the question, the answer is added to the Q&A database. Therefore, as the Q&A database accumulates questions and answers, the hit rate grows over time. Beyond these functions, the Answer Machine also provides other services, such as the Hot Spot of Lesson, the Hot Spot of each chapter which is likely to help students to find out what questions are frequently asked and what the correct answers are.

5.2 Data Analyze Center and Learning Community

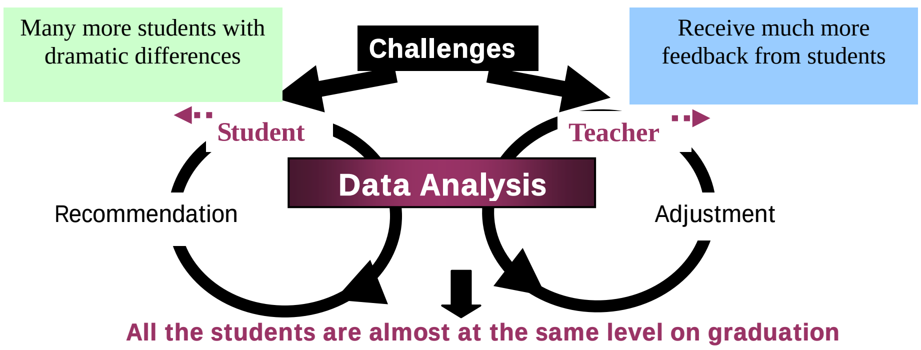

Fig. 4. Data analysis center

In china, the size of E-Learning classes is much larger than normal classes. As against the traditional education, there are several challenges: we have many more students with dramatic differences that they have different backgrounds with the dynamic knowledge structure; given such diversity, how do we construct learner profiles and analyze students learning behaviors? How do we provide personalized services based on the learner profiles and learning behaviors? Furthermore, how do we send the feedbacks of learning states to teachers? In order to answer these questions, we developed a system ---the Data Analysis Centre, to monitor the whole process of teaching and learning, to analysis the student study behavior, and then to provide personalized learning services (Figure 4). As is well known, the learning behaviors are very complex. During the learning process, learners will browse online courses, query the course materials, submit questions, perform examinations, and so on. All of these behaviors represent the learning interest and intent of the learners. We collect all these activities in the log files for further analysis.

From traditional face-to-face lecturing to virtual network classroom learning, users have experienced the deficiencies of lonely learning. Thus collaborative learning is proposed to tackle this problem. Learners exist in learning communities and learn through communities. Every learner in learning community is either the consumer or the provider of knowledge. And the learning goals could be fulfilled though helping one another in the learning community. We implemented a prototype of self-organizing learning community[18] to cluster learners automatically and quickly, which also could help learners share their learning experiences and insights and exchange learning materials during the learning process.

5.3 Personalized Course Generation Based on Social Annotated Resources

The big ideas of 2.0 encourage participation, are inherently social and open. These principles are in line with modern educational theories such as constructivism and connectionism and thus make Web 2.0 applications very attractive for teachers and learners. Wikis, blogs, and social bookmarking are now commonly used in learning [1]. Web based courses have become popular ways to distribute learning content to learners but “one size fits all” solutions are no longer enough to satisfy the learner’s educational needs. The lack of sharable and reusable learning resources put most personalized systems into the embarrassment of cooking a meal without rice. Authoring learning resources is a time consuming and difficult task. We proposed and implemented a mechanism of harnessing the power of the crowd (principle of web 2.0) to social annotate learning resources for the personalized course generation system[14]. With this method, the lectures and developers could use very few effort and time to make very tedious and complicated work easier and feasible. Students from both traditional classes and online learning could benefit from our personalized course generation system. We are currently using this system to collect data for the SJTU course of “Web Services and .NET Technologies”.

6. Conclusion

This paper presented an overall pervasive e-Learning platform which provide “always on” education. Students could access the live interactive lectures and asynchronous web-based learning services anytime from anywhere using diverse network devices. The multi-modal interactions supported at this platform enables teachers to give lectures in a natural way and thus eliminating the limit of desk based tele-education systems. Data collected revealed interactions could much better engage students in the learning process and students changed from passive learners to truly engaged learners who are behaviorally, intellectually, and emotionally involved in their learning tasks. The pervasive e-Learning system described in this paper is used by the SJTU online college with 17,000 enrolled students, which makes this platform an ideal large-scale test-bed for hybrid learning. The platform described in this article helps the college yield higher profits than ordinary colleges that one administrator could manage 1000 students and one teacher could give a class of 1000 students. In the future, researches on leveraging emerging technologies to provide more efficient learning services on this pervasive learning platform will always be encouraged and conducted.

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