

# A Mixed Reality Approach to Hybrid Learning in Mixed Culture Environments

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## **ABSTRACT**

*This chapter describes a conceptual framework that aims to augment existing eLearning systems with a 3D virtual classroom environment to provide geographically dispersed online learners with a sense of being together and part of a natural class. The virtual classroom model the authors present is based on a combination a ‘massively multi-user’ games technology system from Sun Microsystems Research Labs, a distance learning platform based at Shanghai Jiaotong University and a mixed reality environment developed at Essex University. Learning is, to some extent, a social activity as it involves relationships between people (between students, between students and teachers). Networked technology has a global reach bringing not just new opportunities but also complex multi-cultural and pedagogical issues. Thus, in this chapter the authors discuss both the technology and the socio-educational aspects of designing online Mixed Reality Hybrid Learning systems*

## **INTRODUCTION**

The Internet has opened the possibility for “anyone, anytime, anywhere” communication, accelerating the pace of globalisation, as network services become affordable international commodities consumed by an increasingly multicultural market. For example, banking services are available via the Internet 24/7 to account holders as they roam the globe.

Education has the potential to be such a global service. Ron Perkinson, the Principal Education Specialist for the International Finance Corporation (part of the World Bank Group)

estimated that the value of the global education market in 2005 was worth a little over US\$2.5 trillion with the private higher education market being valued at over \$400 billion worldwide (about 17% of the overall education market). In 2005 the international student population worldwide was 115 million, growing at a rate of approximately 15% per annum, with about half of this increase being due to China (Perkinson, 2006). Education is becoming increasingly important in modern knowledge-based economies (Clarke, Callaghan, 2007) where learning is rapidly becoming a life long process, as borne out by figures such as, 40% of undergraduates in US and 65% of students enrolled in Singapore's private higher education establishments are over 25. Such facts speak for themselves and form a driver to find effective new ways of meeting the growing demand for learning services.

In a parallel trend, online games are growing massively in popularity. According to a survey by comScore, a market analyst company, there are 217 million online gamers worldwide (double the number of students), growing at a rate of 17% per annum<sup>1</sup>. The market analysis firm DFC Intelligence, has estimated that the worldwide online game market is worth around \$4 billion now and will grow to \$13 billion by 2012 with about 50% of the market being the Far East, 25% in the USA and 18% in Europe. Major markets such as South Korea, China, Japan and the US all gross over \$100 million per annum. For example the Chinese online gaming market value in 2007 was some \$1.2 billion (9.36 billion Yuan) with the number of online gamers in China estimated at around 59 million in 2008<sup>2</sup>. Males continue to dominate the online gaming market although the gender gap is narrowing in countries such as Malaysia, Singapore and Korea where the female gaming population stands at 48 percent, 47 percent and 36.5 percent, respectively. The networked nature of the technology gives it a global, location-independent reach, creating massive commercial opportunities. For example a single game, *World of Warcraft*, from Blizzard Entertainment, grossed over \$100 million in several different countries in its first year. We share the view that network education and Massively Multi-User Games (MMUG) technology share a common computational framework and that the massive investment in games technology could be synergistically exploited to provide cost effective forms of educational services to a diverse multicultural audience (Winston, Moore, Pearson, Hall, Shadbolt, Weston, 2008).

This chapter seeks to show how traditional eLearning systems can be augmented with games technology to provide an increased sense of realism for multi-cultural online learners (our aim is to provide as natural a feel to online lectures, as possible). We approach this by first describing our existing eLearning system based at Shanghai Jiao Tong University and secondly by describing our mixed-reality environment (Mirtle) based at Essex University. We then present our work on Socio-Educational aspects of learning, such as multi-cultural issues from San-Diego State University, before concluding with a discussion on how these approaches might be integrated into a single framework.

## Background

### Online Learning Systems

The rapid evolution of information technology has led to new ways of learning and education. Many education institutions and corporations promote eLearning to provide better learning and teaching environments. Products such as WebCT<sup>3</sup> and Blackboard<sup>4</sup> have been in use for the past

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<sup>1</sup> [www.comscore.com/press/release.asp?press=1521](http://www.comscore.com/press/release.asp?press=1521)

<sup>2</sup> [http://news.xinhuanet.com/english/2008-01/21/content\\_7467275.htm](http://news.xinhuanet.com/english/2008-01/21/content_7467275.htm)

<sup>3</sup> [www.WebCT.com](http://www.WebCT.com)

<sup>4</sup> [www.Blackboard.com](http://www.Blackboard.com)

few years. Many online colleges such as the UK Open University<sup>5</sup>, the Hong Kong Open University<sup>6</sup> and the Network Education College of Shanghai Jiao Tong University<sup>7</sup> have developed and deployed their own eLearning platform and infrastructure to provide adaptive and efficient eLearning services. Today, eLearning has become heavily learner-centred, emphasizing pervasive and personalized learning technologies (Thomas, 2008). As both the traditional classroom learning and web-based learning offer strengths and suffer from limitations, it is now a trend for eLearning systems to combine the best aspects of the two into blended learning (Kim 2007). Blended learning (BL) integrates seemingly opposite approaches, such as formal and informal learning, face-to-face and online experiences, directed paths and reliance on self-direction, and digital references and collegial connections (Rossett, Frazee, 2006). In our approach we blend natural class derived lectures, packaged in a classroom setting using both live video and simulated rooms, together with archived and offline activities afforded by the system and wider infrastructure.

## Online Games

We contend that online education can benefit from developments in the computer games industry, which enjoys massive industrial investment. Thus, whilst this paper is not advocating the use of games as an instrument of learning (although we recognise this is a strong area of research in itself), we are arguing that there is potential synergy in the underlying technology platforms that can support both games and education. In particular, we have identified a commonality with virtual environments. As part of supporting this hypothesis, we review the relevant aspects of the games industry.



Figure 1 – Sun's Wonderland Environment

Originally computer games were designed to be used by a single person or a small group via a local network. However, with the advancement of the Internet, new categories of games emerged specially designed to exploit global connectivity. Online games, such as the *World of Warcraft* MMORPG, (Massively Multiplayer Online Role-Playing Game) series by Blizzard Entertainment<sup>8</sup>, brought simulator modelling to new levels by offering vast, highly detailed worlds to be simultaneously used by large numbers of online users. Broadband technology has allowed this medium to extend further, with higher data-transfer speeds making it possible for

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<sup>5</sup> [www.open.ac.uk](http://www.open.ac.uk)

<sup>6</sup> [www.ouhk.edu.hk](http://www.ouhk.edu.hk)

<sup>7</sup> [www.nec.sjtu.edu.cn](http://www.nec.sjtu.edu.cn)

<sup>8</sup> [www.wow-europe.com](http://www.wow-europe.com)

detailed worlds, normally found in offline games, to be brought online. The latest generations of computer games consoles have been designed for broadband Internet connectivity, allowing traditional offline game genres (such as racing) to be updated so players can challenge opponents online from anywhere in the world. The success of computer games that were designed to be played online has led to a new genre of online social communities (for example, Linden Labs, Second Life) where people can log-in to the virtual world “seeing” and “interacting” with other users, without any of the mission-based objectives or tournaments found in traditional online computer games. Second Life<sup>9</sup> has expanded to the point where businesses have been established in the virtual environment, with real-world money being exchanged for products and services traded within the virtualised space. Several real-world multinational companies and “high street brands” have opened their own Second Life virtual outlets<sup>10</sup>, and some real countries, such as the Maldives and Sweden, have even created their own Second Life embassy<sup>11</sup>. Traditional universities are also beginning to offer services in online virtual worlds; for example, Harvard Law School set up a simulated courtroom in Second Life where students can practise their advocacy skills whereas Edinburgh University uses it to deliver an MSc course on eLearning (Shepherd 2007). Currently (2008), over one hundred higher education institutions are listed on the Second Life site with many enthusiastically pursuing the vision for a globally networked virtual classroom environment<sup>12</sup>. Another notable example is the Sun Microsystems’ MPK20; a virtual meeting environment for supporting Sun’s business activities<sup>13</sup>.

In our work we are using such online social community game environments to host our virtual classroom environment, in particular, we have chosen Wonderland as our development platform (see figure 1). In the following paragraph we will discuss Second-Life and Wonderland in a little more detail, with a view of understanding the key issues, which affect the choice of platform.

The development of the Wonderland platform by Sun Microsystems was originally conceived as a tool to support collaborative working by the workforce within Sun. As such it had a number of clear design goals, which were to:

- Focus on social interaction, formal and informal
- To be emotionally salient
- Have a strong sense of social presence, allowing for discussion of sensitive topics
- Have spontaneous, unplanned interactions, particularly socializing before and after planned events to build trust
- Enhance communication during formal interactions
- Be designed for collaboration
- Have a seamless document sharing with no need to switch contexts
- Have extreme extensibility
- Allow developers to add any sort of new behaviour

As such the key strengths of Wonderland can be characterised as:

- Support for live application sharing
- Ability to integrate with business data
- Internal or external deployment options
- Highly scalable

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<sup>9</sup> secondlife.com

<sup>10</sup> news.bbc.co.uk/1/hi/technology/6054352.stm

<sup>11</sup> news.bbc.co.uk/1/hi/world/europe/6310915.stm

<sup>12</sup> secondlifegrid.net/how/education\_and\_training

<sup>13</sup> research.sun.com/projects/mc/mpk20.html

- Support for very large to very small groups
- Open and extensible (open source, open art path)
- 100% Java
- Spatial audio as a core feature
- Extensive telephony integration

Wonderland is therefore very different to the commonly used SecondLife platform. The Wonderland platform is primarily intended to be tailored and integrated by organisations within their own infrastructures whereas Second Life is a publicly accessible online<sup>14</sup> service with very large numbers of users who can make use of a virtual economy to organise their lives. However, SecondLife has been used extensively by teaching institutions to carry out online teaching<sup>15</sup>. There is no doubt that SecondLife has been used very successfully to support online teaching and learning. However, there are several issues around its use, particularly concerned with the privacy and security for participants taking part in online sessions, and whether there are sufficient controls in place for organisations to use it as part of their formal teaching infrastructure.

At its core, SecondLife is a commercial operation which has its own set of imperatives. However, it does service a very large community (comScore reported nearly 1.3 million people logged in during March 2007), and particularly has key strengths in a number of areas, such as the ability to add behaviours to worlds using a rich scripting language (LindenScript) and the relative ease of creating 3D objects and adding them to the world.

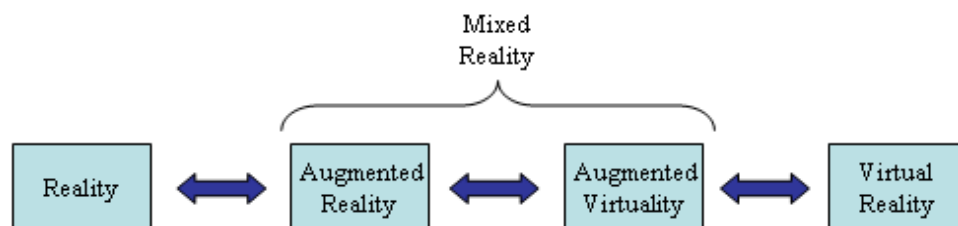


Figure 2 - Milgram's Reality-Virtuality Continuum

As an alternative to SecondLife, there is the open source Opensim platform<sup>16</sup> which can be used to create a SecondLife-like environment, “able to run in a standalone mode or connected to other OpenSimulator instances through built in grid technology”. The providers claim “it can also easily be extended to produce more specialized 3D interactive applications”.

This is, in effect, a Second Life compatible server (Second Life has already open sourced their client), which can be installed and modified as needed by organisations. The OpenSim Grid capability is particularly interesting as it allows different worlds to be linked and promises to provide an easy mechanism for users to move between different worlds. However, it is not as platform-agnostic as Wonderland as it relies on the Mono and .Net software frameworks.

More advanced approaches are exploring connecting the real-world with a virtual environment. Collectively known as Mixed-Reality, this term can be broken down further using the Reality-Virtuality Continuum (see figure 2) (Milgram, Kishino, 1994) into: a) Augmented Reality, where the system consists of virtual components being added to a real-world environment (Hughes, Stapleton, Hughes, Smith, 2005); and b) Augmented Virtuality, where real-world features are added to a virtual environment (Davies, Callaghan, Shen, 2007) (Davies,

<sup>14</sup> Since writing the first version of this chapter, in November 2009, Linden Labs announced an enterprise version of Second Life that can be located on a company's server and intranet, closed off from the public internet

<sup>15</sup> <http://blogs.sun.com/wonderland>

<sup>16</sup> [opensimulator.org](http://opensimulator.org)

Callaghan, Gardner, 2008). Such technological advances underpin our vision to bring innovative mixed-reality solutions to remote education environments.

## Cultural Models for Designing Culturally Sensitive Instruction or Games

Teaching is a profoundly cultural act raising important socio-educational issues. Challenges associated with any cross-cultural interaction, such as the misunderstandings that arise from our unknown assumptions, also influence teaching and learning (Hall 76). As Pai and Adler argued, culture and education are inextricably related; and they “define” each other. “The processes of teaching and learning are influenced by the core values, beliefs, and attitudes, as well as the predominant cognitive and communication styles and linguistic patterns, of a culture” (Rogers, Wang, 2008).

With the increasing global outreach of online programs and courses, there is a great need to design and deliver online learning that can be engaging to a culturally diverse audience. Several models have been suggested for creating online instruction, each illuminating important considerations. Researchers have suggested adding a cultural dimension to the widely used instructional design model--ADDIE (Analyze, Design, Develop, Implement, and Evaluate) (Thomas, Mitchell, Joseph, 2002). This cultural dimension consists of intention, interaction, and introspection. The intentional attribute of learning would encourage the designer to consider and make their cultural bias explicit. The interaction parameter would involve the collaboration of designer, subject-matter expert, and end-user throughout the model phases to facilitate the melding of culture into the end product. Finally, introspection on the part of designer ensures that he or she is considering his or her own thoughts, beliefs, attitudes, desires, and feelings toward the cultures represented in the instruction. A Cultural Adaptation Process model has been proposed that helps to categorize culturally adapt materials for particular learner groups based on the type of content, instructional methods, and media used (Edmundson 2007). A “multiple cultures model” emphasizes the importance for sustainable learning outcomes to include elements from both the learner’s own culture and those from the emerging global academic or training culture (from industry, government, or higher educational institutions) (Henderson 1996).

Because of the instant nature of the interaction, virtual learning environments (including online games) pose greater need for cultural considerations. In addition, a game itself is a cultural activity and it thrives on being interesting and engaging to players around the world. Players need to be able to communicate, share understandings, follow the same rules and be part of an international team to carry out the tasks as designed. However, the aforementioned models address cultural issues in designing or conducting formal instruction. Social and cultural aspects of online games are becoming a popular research topic. In this chapter, we attempt to address some of the cultural challenges when adopting learning and games technology in virtual or hybrid environments. It is worth noting that whilst this project is operating as an international collaboration, our initial deployment plans are to provide the service within a single country (looking at the consequences to the technology for differing cultural settings). In later work we plan to extend this to address cross cultural operation (eg supporting students in multiple cultures). In the following we first introduce the host eLearning environment (the Shanghai Jiao Tong NEC); we then describe the virtual reality environment that will be added to it (the Essex MiRTLE system).

## THE SHANGHAI E-LEARNING PLATFORM

The e-Learning system developed at the SJTU Network Education College (NEC) acts as the host platform for the virtual reality-learning environment (MiRTLE). As such the NEC platform

provides the essential infrastructure to manage and deliver lectures to students in a real classroom, at home or even outdoors. Currently, the SJTU NEC delivers varied education to some 17,000 China based students. The philosophy underpinning the SJTU NEC is that natural classrooms and traditional teaching are the best means to deliver high quality education to students. Thus, the researchers and developers have made great effort to leverage existing and emerging ICTs to augment the function of a traditional classroom and to digitalize the content, so as to deliver lessons to geographically distributed students. At the same time much effort has been made to give the online students a feeling of being in a real class wherever they may reside.



*Figure 3 - A typical SNC in use at the online college*

The Shanghai e-Learning platform provides “always on” hybrid learning services which are accomplished through extending the real classrooms and also supporting web-based adaptive learning. The core of the platform are distributed Standard Natural Classrooms (SNC), which are high-tech spaces to provide natural human-machine interaction and context-aware services for teachers and students (see figure 3). They are equipped with numerous smart devices/sensors and specially developed software. The fully interactive lectures are then delivered to PCs, laptops, PDA, IPTV and mobile phones in real-time by using large-scale media streaming to multi-mode terminals through heterogeneous networks. Enabling this real-time (live) connection between the teacher and students is a considerable challenge, but this is a distinguishing feature of the Shanghai approach. Later, we will explain how the virtual classroom seeks to promote further the natural classroom model, by providing a simulated online classroom that aids dispersed online learners to feel part of a real class.

### **The Standard Natural Classrooms (SNC)**

As was explained earlier, the motivation underpinning the work at Shanghai Jiao Tong e-Learning Lab is to create teaching and learning environments that are as natural as the technology allows. This contrasts to most other approaches that are akin to television studios or videoconference systems. In many of these systems teachers are required to remain at a computer, using the keyboard and mouse to manage the lecture that, in addition to limiting interaction, scalability, mobility and maintenance also loses much of the effectiveness of traditional classroom education. This weakness is widely recognised and much effort has been made to bridge the gap between real-time remote classroom and traditional classroom activities in projects such as the Tsinghua University Smart Classroom (Shi, Xie, Xu, 2003).

By supplementing real classrooms with pervasive computing technologies we have created numerous SNCs across China. These classrooms are equipped with high-tech devices, tools and software infrastructure that are configured in a unified *standard* way. In these classrooms, teachers can move freely, use multiple *natural* modalities to give the lecture and interact with remote students as they would in traditional classrooms. The classrooms are interconnected through broadband IP network or through two-way satellite links. Depending on the student's circumstance they can select to attend the class in person (where the lecturer is), visit a remote centre (with an interactive video feed of the lecture) or view the lectures in their own home or on a mobile phone. Figure 4 shows the classroom setup of a typical SNC in use at NEC. The touch screen display and interactive whiteboard and presentations (e.g. PowerPoint) allow the lectures to be delivered whilst capturing spontaneous interaction such as handwriting. A special 'Laser e-pen' gives the lecturer the freedom to write from any position in the classroom. To optimize the video scene, a pan-camera automatically tracks the instructor when he/she moves about in the classroom. An additional camera faces the students to measure their attention, which provides useful feedback to the teacher when optimising the pace of the lecture. A feedback screen, facing the lecturer, displays the questions and poll results, which the teachers can use to fine-tune their lecturing. Other devices are provided to collect contextual information and to control the classroom equipment. For example, RFID (Radio Frequency Identifier) tags are used to identify and track students and occupancy sensors manage the lighting. 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.



Figure 4. The typical SNC setup

Technologies are leveraged to support multi-modal interactions in our SNCs. The students-teachers interactive communication is dealt with in a natural way through handwriting, audio command and laser pen, thus eliminating the limit of desktop based interaction in traditional tele-education systems. In previous studies this has been found to help change students from passive learners, frequently observed in traditional eLearning, to engaged learners who are behaviourally, intellectually, and emotionally involved in their learning tasks (Wang 2007). During lectures, the live classroom scenes are transmitted to remote SNCs and displayed on wall-mounted large screens. Simultaneously, video from the remote SNC are transmitted back to the lecturer. For learners using PC at home or mobile devices, the live teacher's video is delivered together with the audio and lecture notes (but without any backwards transmission of video from the student's



to the lecturer's environment). When a teacher talks to a specific student, this student's video is transmitted to all the SNCs. The teacher can use voice-commands to perform some common actions such as "next slide" or "previous slide". Students can send text messages to the instructor through their cell phone using an SMS (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 of their learning progress, questions, or any other feedback, that the instructor could respond to.

In a similar way to writing on chalkboards or whiteboards in a traditional classroom, teachers may write on the touch screen with an electronic pen. Such electronic pen writing has the advantage for students of allowing greater focus on the lecture (without the distraction of writing) and sharing a common writing medium between remote environments (including remote students using PCs or mobile devices). For instance, a student might write the solution to a question that the teacher has just posed. The teacher's freedom is further enhanced as the laser pointer allows them to write on the projected screen. Emotion aware technology is also employed and is described in the MiRTLE section.

## Large Scale Media Streaming

The aim of pervasive learning is to enable learners to access education resources using any available network devices anytime, anywhere. The SJTU NEC platform supports three types of multimedia access:

- Live lecture broadcast,
- Lecture-on-demand (LOD),
- Downloading archived lectures.

The challenges here range from the adaptation of educational content based on the current context (eg device computing capacity, screen size and network bandwidth etc) to considerations of efficient and reliable media transmission for large-scale concurrent user access.

Typical media streaming e-Learning systems are one-to-many (eg one lecture delivered to many locations) or, less frequently, many-to-many (eg tutorial or project discussions). One-to-many multicasting can dramatically improve the 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 protocols and robust congestion control mechanisms make it difficult to implement on heterogeneous inter-networks such as CERNET (Chinese Education and Research NETWORK), telecom ADSL, dial-up network or mobile networks. 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 support from routers, flexible congestion control mechanisms could be exploited to ensure the quality of data transmission. In recent years, application layer multicast (ALM) has gained more attention amongst researchers. In pervasive learning environments, users are either based in remote classrooms, at home or mobile with users being distributed as a sparse mix of heterogeneous technologies. Therefore, our implementation takes the form of a hybrid multicast model that combines ALM and IP multicast running on a tree-like network topology. Data is distributed in two ways, either in the form of tunnel distribution (based on UDP unicast at the application layer across different multicast domains) or IP multicast within a multicast domain.



Figure 5 - Live Lecture on a mobile phone Nokia 6600

We also provide content adaption for different user devices, especially for mobile users. When participating in live class, students presently have four media configuration options:

1. Active presentation (eg PowerPoint), audio, and a small video of the real-time classroom,
2. Video and audio of the instructor only,
3. Enlarged display of the active presentation with audio
4. Close-up display of the instructor's facial expressions and their body language with audio.

A recent survey at SJTU NEC revealed that 85% of the students prefer option 1 (Wang, Shen, Novak, Pan, 2008). The students generally held the opinion that the presentation, audio, and video mode provided a better context for learning. One factor was that this configuration gave a better feeling of being in a real classroom with the instructor and many other students nearby. Catering to this need we have provided three types of media streams for mobile users:

1. An instructor's presentation screen from his desktop
2. The instructor's facial expressions from a video camera, and
3. An audio stream of an instructor's voices from a microphone.

Mobile phones need a GPRS (General Packet Radio Service) or CDMA (Code Division Multiple Access) capability to work with the eLearning platform. However, GPRS bandwidth is relatively small, being approximately 28.8kbps for downloading and 10kbps for uploading. Thus each of the three streams is reduced to 8kbps, so that it can fit to the available bandwidth of GPRS. Figure 5 shows a typical display on the mobile phone (Nokia 6600).

## Adaptive and Personalized Web-Based Learning Services

The web-based learning system provides services which students can use to conduct asynchronous self-paced learning anytime anywhere. It comprises the following components:

1. Content based retrieval search engine - enables the students to find their desired materials conveniently and quickly
2. Answer machine - responds to students' questions automatically,
3. Data analysis centre and self-organized learning community - analyses students learning patterns and provides personalized services
4. Miscellaneous tools - assignment system and examination system.

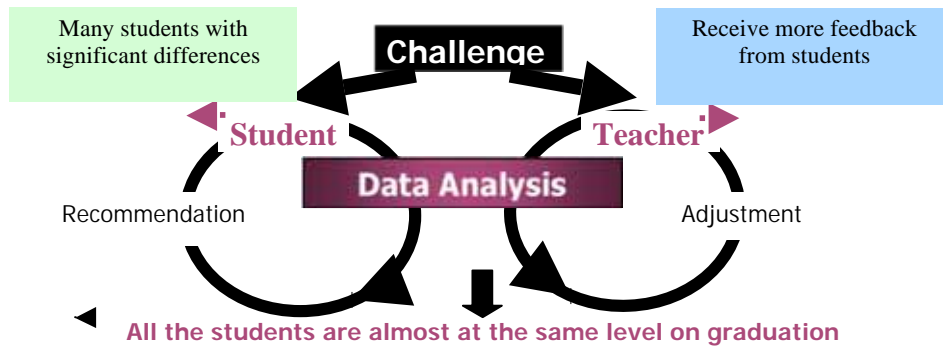


Figure 6 - Data analysis centre

We now, by way of an example, introduce the data analysis centre. E-Learning classes can be an order of magnitude larger than traditional classrooms. This raises several challenges such as a much-increased diversity in student ability and progress. E-Learning students come from different backgrounds, bear highly diverse knowledge structures and work in every walk of life. Thus, a challenge is, given such diversity, how do we provide personalized services based on the learner profiles and learning behaviours? Furthermore, how do we provide feedback on learning states to teachers? In order to answer these questions, we have developed a component we refer to as the Data Analysis Centre, to monitor the whole process of teaching and learning, to analysis the student study behaviour, and to provide personalized learning services (see figure 6). As is well known, learning behaviour is very complex. During the learning process, learners may browse online courses, query the course materials, submit questions, perform examinations, and so on. All of these behaviours represent the learning interest and intent of the learners. We collect all these activities in log-files for further analysis.

Both traditional and online learners experience deficiencies rooted in their isolation, sometimes described as 'lonely learning'. To address this issue we employ collaborative learning methodologies where we group learners into communities of similar educational state and introduce learning that requires group interaction. Every learner, in a learning community, is either the consumer or the provider of knowledge and the learning goals are fulfilled through students helping each other. We implemented a prototype of self-organizing learning community to cluster learners automatically, which helps learners share their learning experiences and exchange learning materials during the learning process (Yang, Han, Shen, Kraemer, Fan, 2003).

As we explained at the outset, our philosophy is to mirror the natural teaching environment as closely as the available technology allows. One particular issue we have encountered is that geographically dispersed learners (eg on a PC in their home) can have a feeling of isolation. In a natural classroom, learners can see and talk to each other. They get both a social and academically supportive presence. In a bid to try to recreate some of the elements of a natural classroom, we have embarked on work of creating g a virtual classroom, where representations of students, in the form of avatars (from games), can inhabit a shared space, either socialising or providing mutual support. Our work towards these aims is described in the following sections.

## MIRTLE

The objective of the MiRTLE (Mixed Reality Teaching & Learning Environment) is to provide an online virtual classroom to augment the Shanghai Jiao Tong e-Learning platform described earlier. It is intended to provide a mixed reality environment for a combination of local and remote students (both dispersed and local students are able to see and talk with each other, in addition to the teacher). The environment is intended to augment existing teaching practice with the ability to foster a sense of community amongst remote students, and between remote and co-located locations. In this sense, the mixed reality environment links the physical and virtual worlds.

### The Mixed Reality Teaching Environment

Our longer-term vision is to create an entire mixed-reality campus but in this paper we describe the core component: a mixed-reality classroom. In the physical classroom the lecturer is able to deliver the lecture in their normal way but they will have a large display screen mounted at the back of the room that shows avatars of the remote students who are logged into the virtual counterpart of the classroom.



*Figure 7 - Lecturer view of remotely located students*

Thus the lecturer will be able to see and interact with a mix of students who are present in both the real and virtual world (see figure 7). Audio communication between the lecturer and the remote students is made possible via a voice bridge. A camera is placed on the rear wall of the room to deliver a live audio and video stream of the lecture into the virtual world.

From the remote students' perspective, they will log into the MiRTLE virtual world and enter the classroom where the lecture is taking place. Here they will see a live video of the lecture as well as any slides that are being presented, or an application that the lecturer is using (see figure 8). Spatial audio is employed to enhance their experience such that it is closer to the real world. They have the opportunity to ask questions just as they would in the physical world via audio communication. Additionally a messaging window is provided that allows written questions or discussion to take place.

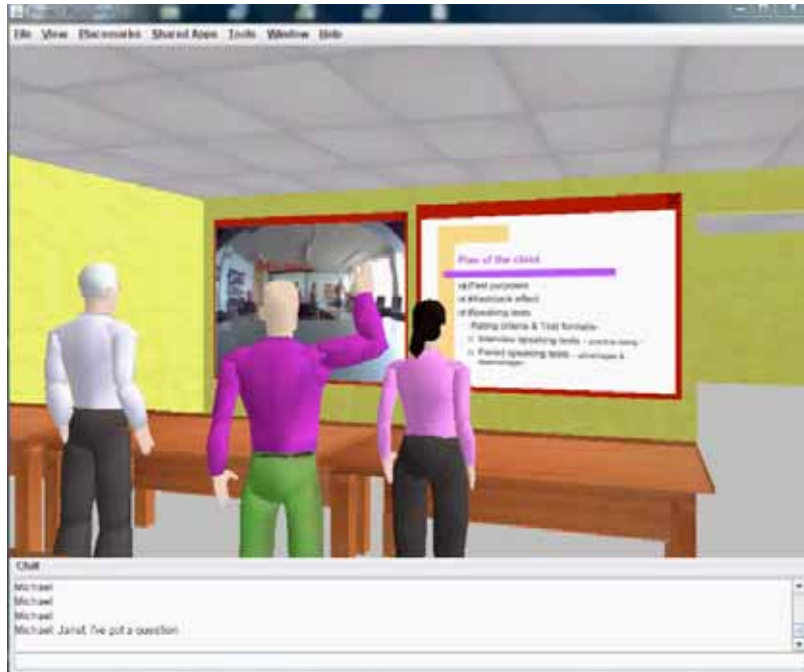


Figure 8 Student View of Lecture

In addition to the virtual-classroom, the MiRTLE virtual world offers a common room where students can meet socially. A demonstration room is provided which is populated with a whiteboard, slideshows and NPCs that, for example, provide an audio commentary to describe the MiRTLE project itself. We intend that this will provide an environment for vicarious learning to take place.

## The Mixed Reality Technology

MiRTLE is built using open source tools, in particular the Sun Microsystems' Darkstar Project and Wonderland platforms. Sun's Project Darkstar<sup>17</sup> is a computational infrastructure to support online gaming (Burns, 2007). Project Wonderland<sup>18</sup> is a client-server architecture and set of technologies to support the development of immersive online simulations, virtual and mixed reality environments. A noteworthy example of this is Sun's MPK20 application; a virtual building designed for online real-time meetings between geographically distributed Sun employees.

## Wonderland

In more detail, Project Wonderland<sup>19</sup> is based on several technologies including Project Looking Glass to generate a scene and jVoiceBridge<sup>20</sup> for adding high fidelity immersive audio. The graphical content that creates the visible world as well as the screen buffers controlling the scene currently uses Java3D. Additional objects/components to Wonderland (such as a camera device to record audio and video, as seen from a client), make use of other technologies such as the Java

<sup>17</sup> [www.projectdarkstar.com](http://www.projectdarkstar.com)

<sup>18</sup> [g3d-wonderland.dev.java.net](http://g3d-wonderland.dev.java.net)

<sup>19</sup> Since writing this paper in 2008, Sun have released a new version of Wonderland (v0.5), which includes many improvements such as support for jME (Java Monkey Engine), a high performance scene graph based graphics API.

<sup>20</sup> [jvoicebridge.dev.java.net](http://jvoicebridge.dev.java.net)

Media Framework<sup>21</sup>. Graphical content can be added to a Wonderland world by creating objects using a graphics package such as Blender or Maya. Project Wonderland, including Sun's exemplar MPK20 environment, is being developed as an open source project that is open to all members of the software development community. However, users of Project Wonderland are not restricted to developers; the project also provides binaries that can be downloaded and extended with user-developed content and worlds.

Project Wonderland provides a rich set of objects for creating environments, such as building structures (eg walls) and furniture (eg desks). An additional feature of Wonderland is its provision of shared applications: standard software applications, such as word processors, web browsers and document presentation tools, can be used and shared by all participants. Thus, for example, a virtual whiteboard can be drawn on by one or several users and PDF documents and the presentations can be viewed. Blender has been used to create the objects that populate the world. These objects are then exported to the X3D open standards file format for use in the world. To aid ease of use, and to ensure that users receive the current version of the client, Java Web Start Technology<sup>22</sup> has been employed.

A distinguishing feature of Project Wonderland is its support of spatially realistic audio, enabling participants to converse and experience a sense of audio direction and intensity of those they are talking to, or hearing in the distance.

A user is represented as an avatar. There are currently two types of avatar featured in the Wonderland environment. First are NPCs (Non-player characters), which are static in the virtual world, often forming background characters, providing audio explanations over the voice-bridge, or otherwise just simply adding to the general ambience of the environment via private conversations between two people. The other type of avatar is the PC (Player Character), which individually represents a single user. Each PC is capable of walking around the virtual world (displayed via an animation). Eventually it is intended that a PC would have an appearance similar to that of its real-world (human) controller, however at the moment, unless coded with a specific template, a simple avatar is automatically generated upon login. To aid identification, each PC avatar is augmented with the login name of its controller. A controller can speak through their avatar to others in the world via the voice-bridge and a microphone and speaker, or use a dedicated chat window for text-based messages. The scene generated by Wonderland can be viewed from first-person or several third-person perspectives. We have used this technology to develop a virtual classroom.

## Emotion Aware Technology

In a traditional class, the flow of learning material between teacher and student is mediated by both verbal (eg questions) and non-verbal (eg a perplexed look) communication. Most teachers recognise that emotion plays a crucial role in motivation, interest, and attention but, in most current online learning systems, there has been a bias towards the cognitive and relative neglect of the affective needs of a student (Picard, Papert, Bender, Blumberg, Breazeal, Cavallo 2004). It has been shown that the human brain is not just purely a cognitive information processing system, but also a system in which both affective functions and cognitive functions are inextricably integrated with each other (Isen 2000). Whilst most online virtual worlds support language communication (eg text, verbal), apart from emoticons in text messaging, there is little non-language based communication support in online environments. In virtual worlds, this problem becomes more acute as avatar representations are used in place of video views of people. Given the importance of non-verbal communication in teaching (eg being able to observe the emotional state of a recipient of learning material), supporting this is important if virtual worlds are to be

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<sup>21</sup> [java.sun.com/products/java-media/jmf](http://java.sun.com/products/java-media/jmf)

<sup>22</sup> [java.sun.com/products/javawebstart](http://java.sun.com/products/javawebstart)

successful for online learning. However, providing such technology presents a formidable challenge. The most widely used techniques in affect recognition involve facial expressions and body gestures (Chen, Huang 2000) (De Silva, Miyasato, Nakatsu, 1997), speech (Amir, Ron, 1998) (Dellaert, Polzin, Waibel, 1996), physiology (Leon, Clarke, Callaghan, Sepulveda 2007) (Lisetti, Nasov, 2004) or a combination of multiple modalities.



Figure 9 – The Physiological Emotion Sensing Hardware

In the MiRTLE project we have addressed this issue by developing an emotion sensing system based on interpreting physiological signals from a small ‘skin contact’ sensor connected to a Sun Small Programmable Object Technology (SPOT)<sup>23</sup> wearable wireless computer (see figure 9) as a means of interfacing between physical and virtual worlds.



Figure 10 - Russell's Circumplex Model of Affect

Emotion recognition methods based on physiological signals have been widely researched and offer some advantages when compared to alternative techniques. They are well suited for real-time use (Leon, 2007) and can recognise a plethora of distinct emotions. The only requirement is the use of a biophysical sensor which is usually small and non intrusive. The MiRTLE sensor takes the form of a finger clip, shown in figure 9. It has been shown that emotions can be

<sup>23</sup> [www.sunspotworld.com](http://www.sunspotworld.com)

described in terms of arousal (degree of excitement) and valence (negative/ positive emotion) (Lang, 1995). A model of emotion, as a function of arousal and valence, was proposed by Russell (figure 10) (Russell, 1980). Skin resistance has been shown to be a useful way of sensing arousal (Picard 2001] and heart-rate provides a method of obtaining valence (Hanjalic, 2006).

We have conducted a preliminary study on an affective model for eLearning that uses the system shown in figure 9 to detect emotions from physiological signals (Shen 2007) (Kalkanis 2008) (Shen 2008). In more detail, the physiological data for emotion detection used by our prototype is derived from two bio-sensors measuring skin conductance (SC) sensor measuring electrodermal activity and a photoplethysmograph measuring blood volume pressure (BVP) and heart rate. Using this prototype we have achieved a best-case accuracy (86.5%) for four types of learning emotions (Shen 08). Emotions are shown on avatars as colours, which are then interpreted by other occupants of the shared virtual space (both students and teachers).

In addition we are investigating the use of this technology on the core SJTU e-Learning platform to act as a context sensor, which would automatically mediate the flow of educational content to learners using, for example, mobile phones. We are also using the emotional data to provide a class 'emotion meter' to provide composite feedback to lectures, so they can adjust their delivery accordingly (Shen 07).

## **MiRTLE Deployment Issues**

Figure 11 illustrates the deployment of MiRTLE within a basic institutional infrastructure. The key components for MiRTLE are the Wonderland server which hosts the virtual world and manages the interaction with the client machines, and a shared applications server that uses VNC (Virtual Network Computing) to host shared applications that are used within the MiRTLE world (eg. shared office applications, web-browsers, desktops, etc). This shared application server is particularly important, as it is used by a real-time class to host the display of the lecturers presentation, which is synchronised with the main display in the real lecture room and the in-world display to the online students. This ensures that the students in the real classroom see the same slides as the students in the virtual classroom. At the time of writing (2008) the cost of such a minimal entry-level system is of the order \$25,000.



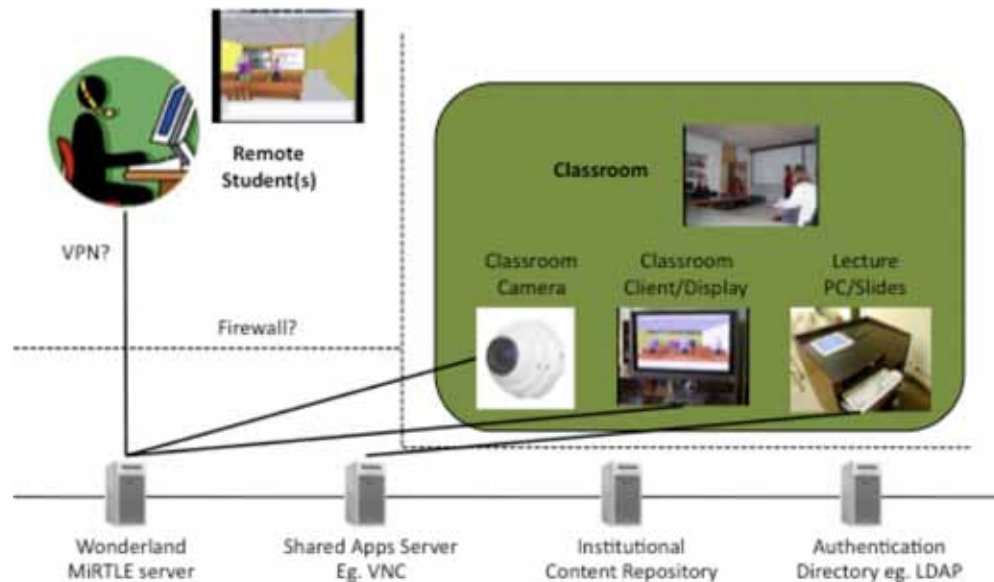


Figure 11 - MiRTLE installation

Mirtle has been designed to be used by non-technical people. From the lecturers point of view working in Mirtle should be no different to their normal routine of using the class audio/visual podium to control their slides. This is however, just the minimal set of components required to host MiRTLE. Most institutions would also make use of content repositories and learning management systems (such as Moodle) to manage their content and lecture materials. Also, there is an authentication system that controls access to university resources, which can make use of a user directory (such as LDAP) and identity management controls. Thus, the implementation requires a number of key components to be integrated together.

Further complications may arise depending on the intended use of the system. For example, if the MiRTLE system is only intended for internal use within a university, it is likely that most of the system components will reside behind the universities firewall. However, given the system is designed to support remote students this may then require a VPN (Virtual Private Network) to be setup to allow remote users (eg. students at home) to log into the system and make use of these university resources. Alternatively it is possible to consider a hybrid solution where certain components (such as the main MiRTLE server, classroom camera, etc) are publicly accessible, and other components (such as the institutional content repository) remain behind the universities firewall. This is further complicated when more advanced scenarios are considered, such as having multiple MiRTLE teaching rooms located in different institutions, and with remote students also participating from different locations. This would require the use of a federated access management system (such as Shibboleth) to control and manage access to all of the shared system resources within a given federation, allowing Darkstar-based students access to the full range of educational media available in the SNC.

As in the existing Shanghai platform, to access the system students need to use the Internet (broadband or GPRS) to log onto the Sun Darkstar server in Shanghai that, in turn, will create an avatar representation of them (which they will have previously selected as part of customising their account). We are planning to use such customisation as one of the vehicles to explore the

effects of cultural diversity by providing a rich set of operational modes that will reflect social preferences. For example, students will be able to create environments in which they are isolated or highly social avatars. Likewise the amount of personalised information available to other online students will be under their control, as will some of the options for interaction with lecturers and other students. In the following section we will discuss some of these issues.

## **SOCIO-EDUCATIONAL ISSUES**

### **Cultural effects in Student Engagement**

With the increasing global outreach of online programs and courses, designing and delivering online learning that can be engaging to a global audience is an area that is in need of more systematic research. Recent studies have revealed that learning outcomes improve when learners are better engaged in learning, such as by establishing their own goals, exploring appropriate resources, and working with others in groups (Picciano, 2002) (Wang, 20004) (Wang, 2006). In an online setting, students may present themselves cognitively, socially, and emotively (Wang, 2007). Social presence is about presenting oneself as a “real person” in a virtual learning environment. Cognitive presence is about sharing information and resources, and constructing new knowledge. Emotive presence is about learner’s expression about their feelings of self, the community, the learning atmosphere, and the learning process. Research into online pedagogies (Cybergogy) of engaged learning through information and communication technologies shows that students learn better when they are socially, cognitively, and emotively immersed in the learning process (Wang,2006).

Cultural attributes, however, can affect online presence and learner perceptions. Learners’ cultural attributes affects how they perceive an online learning setting and how they present themselves online, cognitively, socially, and emotively (Wang, 2006) (Wang C, 2007). Therefore, it is essential that cross-cultural issues in online learning be examined more critically (Rogers, 2008). With the increasing global outreach of online programs and courses, there is a great need to design and deliver online learning that can be engaging to a culturally diverse audience. In the following section we will discuss some of the issues concerned with integrating these approaches on the Shanghai e-Learning platform that will guide our research agenda for our next phase of work.

### **Privacy issues and control of virtual environments**

Privacy is a sensitive issue in pervasive computing systems, one that critically affects the acceptance of networked services by consumers (Callaghan, 2008) (Shadbolt, 2008). A key concern for the use of online services like Second Life is the potential lack of control of the online space, and the privacy of participants taking part, especially given this is an open access commercial platform. Privacy and security is addressed by the Wonderland platform, which aims to solve the problem through the use of its own dedicated open client-server architecture, which can be fully integrated with whatever access and control mechanisms are required. This increasing need to protect data and resources available within virtual worlds is considered by Timothy Wright from the University of Notre Dame in the WonderDAC project<sup>24</sup>. In this project, access in virtual worlds is broadly classified into the following 3 types:

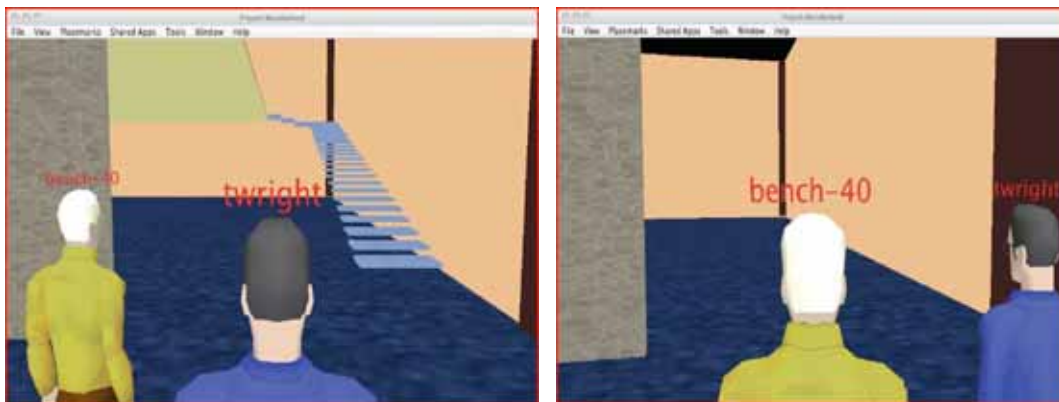
- spatial access (who can move their avatar where)

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<sup>24</sup> <http://blogs.sun.com/wonderland>

- media access (who can view which images or hear what sounds)
- object use/mutability (who can use and change which VR objects)

Most commercial online systems only consider rudimentary spatial access control and ignore more detailed control requirements. WonderDAC (Wonderland with discretionary access control) has developed a simple prototype, to add basic discretionary access controls to the Project Wonderland platform. Further plans are in place to evolve WonderDAC along several lines: spatial object access, non-spatial object access, audio chat access, avatar cloaking, and access to WonderDAC information through a user interface. This is illustrated in figure 12, where the avatar 'twright' is able to see more content than the avatar 'bench-40' based on the access control settings.



*Figure 12 - Discretionary access control in WonderDAC*

## **Pedagogical implications for the use of virtual environments**

Previous research has reported on the need to consider pedagogical principles in the design of new e-learning services (Gardner, 2003). Much of our previous work has been based on adapting the Mayes conceptual framework as a tool to aid in the design and evaluation of e-learning services (Mayes, 95). There is a need for conceptual frameworks that bridge theory and design. Mayes offers such a framework which describes three broad modes of learning which are mapped onto appropriate design principles. The modes or stages of learning are:

- Conceptualisation - the coming into contact with other people's concepts.
- Construction - the building and testing of one's knowledge through the performance of meaningful tasks.
- Dialogue - the debate and discussion that results in the creation of new concepts.

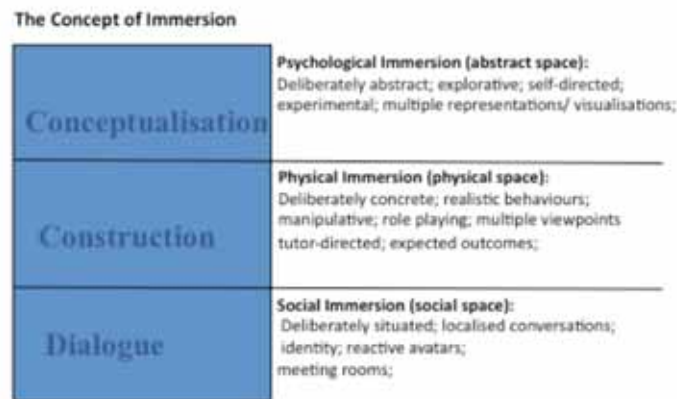


Figure 13 - Mayes and virtual reality

It is important to note that ‘conceptualisation’ is about other people’s concepts, ‘construction’ is about building knowledge from combining one’s own and other people’s concepts into something meaningful. ‘Dialogue’ refers to the creation of new concepts (rather than knowledge) that triggers another cycle of the re-conceptualisation process. Much of our earlier work was based on the use of so-called Web 1.0 technologies, and mapping these to appropriate stages of the Mayes conceptual framework. In MiRTLE we are considering how this can now be extended to include immersive environments. Some useful progress has been achieved by considering this in terms of social networking theories, including the notion of different types of learning relationships (Fowler, 99). However, in terms of virtual environments such as MiRTLE, we need to consider how guidance can be provided to fully exploit the characteristics of these environments. In particular, we need to go beyond just purely emulating current practise (which in effect is what MiRTLE is doing in terms of using a virtual environment to support online lectures), to exploring new innovative ways of exploiting this technology, which build on the key affordances of virtual reality.

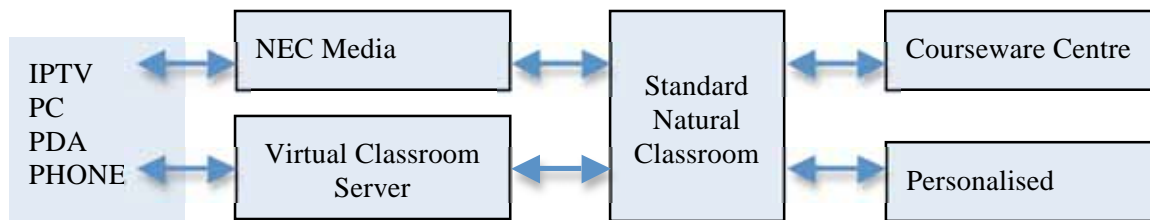
Once characteristic of virtual environments that seems to offer the most opportunity for innovation is that of ‘immersion’. In that it is possible to immerse students in different ways according to their educational need. This has been mapped back to the Mayes framework and is illustrated in figure 13. In this figure, we have identified characteristics of immersion, which are relevant to each of the three stages of the Mayes framework. So for the conceptualization stage, the main emphasis should be on the psychological immersion of the student in the abstract space of the learning domain. For example, this could be achieved graphically by representing the key concepts and relationships of the subject matter, and allowing the student to explore these concepts within the 3D space. For the construction stage, the main emphasis is on the physical immersion of the student within the context of the learning domain. Here we could simulate a particular problem-based learning scenario, allowing the student to experiment with the course of their actions, through this scenario. Finally for the dialogue stage, the main emphasis is on the social immersion of the student with a given social network. Here we consider how the virtual world can facilitate social interaction and collaboration around different domains.

Clearly there remains some way to go in fully developing these approaches. However, if we are to truly offer new and innovative teaching and learning within virtual reality then it is vital

that the development of these systems is grounded within an appreciation of the pedagogy and proper design guidelines.

## INTEGRATED SYSTEM

Figure 14 provides a view of the combined Mirtle and NEC system architecture. In this, SNCs are equipped with numerous cameras and media devices that are offered to the network via a set of powerful media servers. Concurrently another server runs a copy of Sun's Darkstar that maintains an instance of a simulated SNC.



*Figure 14 – The Integrated System*

Video and audio feeds from the NEC media servers are coupled to the Darkstar server that merges the live and simulated feeds and offers them to the wider network. Students using the system use the network to connect either directly to the NEC server, or indirectly via the Darkstar server, which encapsulates the media streams within a virtualised classroom environment. By connecting to either server the remote students can either get direct media feeds or versions wrapped within virtualised classroom delivered to a range of devices such as PCs, laptops, PDAs, IPTVs and mobile phones. Network connections are effected through various networks such as Shanghai Telecom ADSL, GPRS, IPTV, two-way satellite and the Internet. Cultural aspects are encoded as rules and policies as part of the personalisation system, The backend systems consist of the existing e-Learning services described earlier. From figure 14, the system can be seen to be composed of the following main parts:

- a) Standard natural Classrooms – interconnected classrooms fitted with technology to provide natural human-machine interaction and context-aware services for teachers and students;
- b) Virtual Classroom server – a Sun Darkstar server that maintains an instance of the virtual classroom and all the user avatars.
- c) NEC Media Servers - Large-scale media streaming (for multi-mode terminals) delivering fully interactive lectures to PCs, laptops, PDA, IPTV and mobile phones through heterogeneous networks;
- d) Personalised Services- providing multiple services for learning management and quality control, such as dynamic learning services, collaborative learning communities and personalized recommendations. These personalisation services are where the cultural rules and policies are contained
- e) Courseware Centre – a searchable repository for recorded lectures and supporting learning material.

Our work to-date has focused on the technology design, which has been the principal focus of the discussion in this chapter. However, we recognize that as our work progresses the user behaviour, in respect to configuration choices, offers a rich source of research data. For example, choices of virtual versus video environments, use of archived versus live and media preferences can all be instructive for both the underlying technology design and understanding cultural preferences. Likewise, in addition to its role in learning, the emotional feedback intrinsic to the system could provide a useful insight into user issues. Clearly, this is an ambitious vision, with much work remaining to be completed and we look forward to reporting out findings at the various stages of our ongoing research.

## **SUMMARY**

This paper describes a conceptual framework aimed at the creation of a pervasive eLearning platform, sensitive to socio-educational issues, that has the potential to harness emerging technology to support the new globalised digital economy by providing anytime, anywhere, anyone learning.

We have built and tested the Standard Natural Classroom (SNC), the Virtual Classroom (Mirtle) and the affective learning system but, at the time of writing, whilst these have been used and evaluated independently, we have not integrated them nor evaluated them as an integrated whole. Thus, for now, and until we complete this work, this remains a conceptual framework. However, whilst still at an early stage, these are real working systems and we hope that sharing the knowledge we have gained so far will prove useful to others who may be considering such systems.

A fundamental axiom of the Shanghai work is that the learning environment should be as natural (close to the traditional classroom) as the technology will allow. This is facilitated on the Shanghai platform by employing real-time interactive media feeds direct from an actual classroom connecting real students and teachers. Mirtle extends this principle by seeking to provide a means to counter the isolation of remote students who, in traditional eLearning settings, are unable to benefit from the social or collaborative attributes of a natural classroom,

In this work we have explored the feasibility of employing technology that is more commonly used for games which, in addition to increasing the natural ambience of online learning, brings considerable cost and technology synergies by adopting the massive online-games market technology for online-education.

We have discussed various socio-educational issues including culture, privacy and pedagogy. We have recognized the role that social and collaborative learning groups have in learning and we have identified that one of the drawbacks of existing eLearning enterprises is that they are generally devoid of such support. Our principal addition to the e-Learning system was a mechanism to provide such a social sense. Likewise, in order to realise this vision for a globalised pervasive learning environment, we need to understand and cater for the effects of differing cultures. To those ends we are including considerations of the needs of culture in our technological design. For example, the amount and type of interactivity is configurable and avatar appearance will have a multicultural dimension. Finally, we recognise that other human qualities can play an important factor in learning performance and, as part of the social-educational space, we have devised an emotion monitoring and mediation system, as part of this experimental framework.

## **ACKNOWLEDGEMENTS**

We are very pleased to acknowledge John Scott and Marc Davies whose work has contributed to this chapter. We are grateful to Sun Microsystems for financial support of the MiRTLE project and gratefully acknowledge the key role that Bernard Horan and Kevin Roebuck have played in making the MiRTLE project more than a virtual reality.

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#### Indexing Terms:

Hybrid learning – mixed natural classroom and online style teaching

online teaching – network deliver computer based instruction

eLearning - network deliver computer based instruction,

mixed reality – simultaneous use of both real and virtual environments

learning technology – technology used by students

cultural engagement – making technology useful for different races

Smart Environments – technology supported environments