

## DEVELOPING A MODERN INFRASTRUCTURE FOR OPEN DISTANCE EDUCATION IN CHINA: THE IMPLEMENTATION OF THE NCEC PROJECT

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### ABSTRACT

The NCEC project was a joint venture between China and Europe to deliver Internet-based distance education in China. The project was proposed in 1995, sponsored by the European Union since 1998, and finally completed in 2002. This paper shows how the NCEC project was planned and developed, and the importance of its role in the history of Internet application development in China.

**Keywords:** distance education, China, Europe, system design, Internet applications, project management

### I. INTRODUCTION

*"The emergence of the Internet and related networks such as the World Wide Web has had and will increasingly have radical effect on the transformation of education and training in all sectors. The impact is already significant in all developed countries, and the great majority of developing countries are despite difficulties and fears seeking to take part in the emerging global educational community." UNESCO, 2002*

During 1995-2002, we developed and executed the *Network-Training Collaboration in Europe and China* (the NCEC) project<sup>1</sup>, a collaborative Chinese and European Project in Internet-based distance education. We designed a project to allow us to build an international team of researchers to integrate the best of Chinese research in Internet-based learning technology with the standards frameworks being developed in Europe and the USA. The participants of the NCEC project included:

- the Network Research Center (NRC)<sup>2</sup> of Tsinghua University (in charge of the construction and operation of CERNET - China's educational and research Internet),
- Tongji University (one of CERNET's main users),
- Espoo-Vantaa Institute of Technology (EVITech),
- the University of Paisley,
- Fujian Economic Information Center (FEIC, a user of ChinaGBN – the Internet mainly for government applications), and
- New Service Development and Research Center (NSDRC, the major application developers for ChinaNET which is the leading commercial Internet service in China)<sup>3</sup>.

The task of the team was to design and build infrastructure to the emerging standards, such as

- Learning Object Metadata (LOM) [IEEE LTSC, 2003],
- Computing Managed Instruction (CMI) [IEEE LTSC, 2004] and
- Sharable Courseware Object Reference Model (SCORM) (ADL, 2003).

These standards were originated from projects such as Alliance of Remote Instructional Authoring and Distribution Networks for Europe (ARIADNE) [Forte et al, 1996; Duval, 1999] in Europe and the Instructional Management System (IMS) [Anderson et al, 1999] in the USA. Some of the key developers of the NCEC were key partners in the ARIADNE project.

Distance education grew quickly with the development of the Internet, particularly in the USA and the EU. [Potashnik and Corbitt, 1998; USGAO, 2002; Beamish, 2003]. Internet-based education is also diffusing rapidly into developing countries. In China, the adoption of Internet-based distance education has been growing rapidly since 1995<sup>4</sup> [UNESCO, 2002; Carr-Chellman and Zhang, 2000] Although many articles report the progress of distance education research and application in China, little information is available that systematically describes the main research efforts in this area.

The Chinese partners of the NCEC consortium represent major China Internet service providers and clients. The partnership with European institutions helped the NCEC project transfer a set of evaluation methods and standards from complementary European Projects, such as ARIADNE. The partnership experience allowed NCEC to develop and implement authoring standards and forms for the electronic learning objects available via the Internet. The project was a significant attempt to take an EU-USA model of Internet-based learning and deploy it in China using Chinese resources for scientific and technical development.

The launch of the NCEC project in 1995 was an important milestone in China's distance education evolution. Its aim was to design and develop network-based course production,

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<sup>1</sup> The NCEC project is funded by the *EC/Directorate General XIII, Telecommunications*, under the program of *Information Market and Exploitation of Research, Cooperation with Third Countries and International Organisations, Scientific and Technological Cooperation with Developing Countries*.

<sup>2</sup> NRC is also the National Center for CERNET.

<sup>3</sup> NSDRC is affiliated with the Ministry of Information Industry (MII).

<sup>4</sup> A timeline of China's distance education is shown in Appendix I.

delivery, and presentation systems for China to improve the utilization of the Internet [Gordon et al, 1997; Gordon et al, 1999; Lin et al, 2000]The project, sponsored by the European Union since 1998, was completed successfully in 2002. Although it is not the largest in funding and scope among such projects in China over the period, its effects are significant and profound because it was a pioneer distance education project in China and because it was carried out jointly by leading Chinese and European institutions. In addition, the NCEC project was driven by CERNET's initial construction in 1995, and its evolution in technical and managerial aspects reflects advancements of China's Internet technology and the adoption of new concepts in web-based applications. The research outcomes from the NCEC project were applied to other projects.

The NCEC project is not simply an information system project with the application system as the sole deliverable. It also contributed to other intangible objectives:

- it strengthened relationship between European and Chinese partners, and
- it provided learning in adopting Internet technology within a Chinese cultural background.

The main outcomes of the NCEC project included the effects on the evolution of CERNET, the launch of Internet-based college programs in 2001, and the standardization of distance learning techniques in China since 2002. These outcomes are far beyond the benefit from the implementation of the NCEC system itself.

This retrospective paper describes the development of the NCEC from its motivation to its detailed implementation. In this paper, we first address the issues in the NCEC project initiation, such as China's demands for distance education, Internet facility readiness, objectives of the project, and project management (Section II). After presenting the conceptual model of the NCEC system (Section III), we describe the detailed implementation of the system (Section IV). We then discuss the application of the NCEC (Section V). We conclude by reviewing the relationship of the NCEC and other distance education projects in China and Europe and identifying future research issues.

## II. KEY ISSUES FOR THE NCEC PROJECT

China's distance education programs date back to the establishment of the Radio and TV University system (RTVU) in 1960 [UNESCO, 2000; Howells, 1989]. The virtual mega-university in China started to offer degrees for distance education programs in the early 1980s [Keegan, 1994]. The NCEC project was initiated when the Internet in China started to develop, and was conducted when the China's Internet was booming. It was one of the first Internet-based e-learning projects in China, and was the first joint-research project in Internet based education between China and EU countries.

### THE DRIVING FORCES OF THE NCEC PROJECT

The NCEC project was proposed to address to three major needs.

1. The need to bridge the gap between demand for education and the resources for its supply

China's 1999 Annual Statistical Bulletin of Educational Budget [MOE et al, 2000] reported that China's national educational budget in 1999 was RMB 334.9 billion (about US\$41 billion), an increase of 13.56% over that of 1998, and the proportion of state education budget to the GDP was 2.79%. As China has a population of 1.3 billion, the average budget is only US\$30 per capita. The proportion of national budgetary educational fund in fiscal expenditures was 14.49%, which was 0.83% lower than 1998 (15.32%). Among all regions in China, the proportion of budgetary educational spend dropped by different amounts in 13 provinces, municipalities and autonomous regions.

The limited investment in education resulted in insufficient resources to meet the demand for education in China<sup>5</sup>. The proportion of the graduates from primary, junior and senior high schools entering schools of higher education levels is much lower than that in developed countries. According to the 1995 1% Demographic Survey, out of every 100,000 people, 2,065 completed college degree programs, 8,282 graduated from high schools, and 27,283 with an education level at junior middle school. In 1999, only 50% of junior-high school students continued their study to senior-high school and only 63.6% of senior-high school students were admitted to colleges in the same year.

To match education demand due to developments in science and technology worldwide, as well as the intensifying competition in economic and technological fields, we suggest that distance education should be the key to cope with the challenges in education in the 21st century.

## 2. The Growth in Demand for Professional Training

The emerging demand for professional and occupational education and training is another growing area for distance education.

- The demand for re-training the workers that were laid off from state-owned enterprises. The economic reformation in China reached the stage where the majority of state-owned enterprises will have to reduce the number of their employees to improve their productivity. The change of industrial structure now requires new labor skills that cannot be obtained from traditional professional education.
- The demand for continuing professional development and training for those employed to develop competences required by the changing industrial structure in China.
- The demand for re-training redundant government employees. About 50% of government employees have been or will be transferred to industrial sectors. This re-training will help them adapt to new working environments.

We claim that Internet-based distance education will provide the capacity required for professional training in addition to more traditional approaches, such as TV-based education.

## 3. The need to cope with the application demand from fast diffusing Internet in China

The fast diffusion of Internet [Foster and Goodman, 2000; Yin, Yin and Feng 2002] is one of critical factors for the adoption of Internet-based distance education. In particular, CERNET (<http://www.cernet.edu.cn/>) faced the pressure to return benefits from infrastructure investment (Appendix III). Thus, Internet-based distance education became a strategic focus in CERNET's application development agenda starting in 1995.

When proposing the NCEC project, we predicted that the booming Internet in China would further raise the demand for Internet-based distance education. Since 1997, China's Internet has been growing rapidly (Table 1). With a 68 million user population in July 2003, China possessed the second largest Internet population after the USA.

The rapidly expanding user population imposed ever-increasing application demands for Internet applications, particularly in business and education. To cope with this situation, the Chinese government invested heavily in Internet applications. For example, in 2000, the Chinese government spent RMB 360 million (about US\$43 million) in developing distance education in western China [People's Daily, 2000]. The program focused on expanding the existing CERNET, and providing access to CERNET for colleges and schools in the west, especially those for students from ethnic minorities.<sup>6</sup>

<sup>5</sup> Appendix II provides more information about China's education system in the 1990s

<sup>6</sup> The most important factor that enables NCEC is that the end-user Internet accesses, the "last mile", for 1.3 billion Chinese people, has become prevailing in China. These include:

Table 1: Internet Development of China (1997-2003)

Date	Computer hosts (million)	Internet users (million)	Domain name end with cn	Number of websites	Total bandwidth (Mbps)
Nov. 1997	0.299	0.62	4,066	1,500	25
Jul. 1998	0.542	1.175	9,415	3,700	85
Jan. 1999	0.747	2.1	18,396	5,300	143
Jul. 1999	1.460	4	29,045	9,906	241
Jan. 2000	3.500	8.90	48,695	15,153	351
Jul. 2000	6.500	16.9	99,734	27,289	1,234
Jan. 2001	8.920	22.5	122,099	242,739	2,799
Jul. 2001	10.020	26.5	128,362	265,405	3,257
Jan. 2002	12.540	33.7	127,319	277,100	7,598
Jul. 2002	16.130	45.80	126,146	293,213	10,576
Dec. 2002	20.830	59.10	179,544	371,600	9,380
Jul. 2003	25.720	68.00	250,651	473,900	18,599

Source: CNNIC Report 1997, 1998, 1999, 2000, 2001, 2002, 2003

### PROJECT OBJECTIVES

The goal of the NCEC project was defined as:

*With the collaboration of a project team consisting of leading researchers in China and the EU, to implement a pilot network-based collaborative learning system, in order to promote the research and the adoption of new Internet technologies in China during development process of the project and to provide a set of techniques for further application system development.*

Specifically, the scope of the NCEC project contained a demonstrator system with a general function/method set that could be further customized to meet the requirements of different distance education programs. The short-term objectives of the NCEC project based on the prototype system included:

- Building an international development team consisting of leading researchers in China and the EU and establishing the partnership between Chinese and European institutions involved in the project.
- Implementing a pilot of the network-based collaborative learning environment for training, teaching, tutoring, assessment, and for providing feedback to the learners. This environment is accessible to the users (trainees, trainers, and tutors) via appropriate Internet connection.

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- Dial-up access which is popular nationwide since 1998. Because telephone charges are based directly on the time used, users can access the Internet without paying monthly account maintenance fees by calling the 163, 169, or 8163 dial-up services anywhere in China.
  - Internet cafes mushroomed in almost every town in China. Users pay an affordable hourly fee to use Internet-connected computers with broadband services anytime.
  - ISDN services became available in major cities in 2000.
  - Since 2001, broadband services were deployed quickly for home networking. The acceptable cost for the services attracted increasing number of users. For example, ADSL service charges RMB 960 for a three-year contract (about US\$3.50/month), and a cable modem is RMB 90/month (about US\$11/month).

Therefore, THE NCEC project was technically feasible in its proposal stage, and the prediction of Internet facilities readiness proved to be a reasonable forecast of its implementation.

- Promoting research in Chinese courseware management.
- Developing Chinese information processing technology and knowledge management for Chinese information; in particular, promoting the adoption of new international data description standards, such as IEEE LOM, and SCORM, to enable the production and use of advanced learning management software.
- Developing methods and an integrated set of tools for cost-effective production of electronic course materials. The materials designed in accordance with the principles of courseware engineering to enhance the productivity and maintainability of the course materials.
- Carrying out experiments by describing a set of training exercises and delivering pilot courses within the network-based learning environment.
- Providing technology and experience for commercializing the education system.

The long-term objectives of the NCEC project were,

- Realizing China's Internet value by operating the applications that are to be benefited by the research of the NCEC project
- Commercializing the products developed by the project and developing electronic business in distance education.
- Promoting the cooperation between China and EU in Internet application development.

The main development strategy of the NCEC was to use the results from other European and Chinese projects in which the partners were involved. It also provided a clear pattern for the development of collaboration between China and the EU. The lessons learned and the systems built are of significant interest to future EU-CN projects.

### III. THE SYSTEM DESIGN

#### A FOUR-LAYER CONCEPTUAL MODEL FOR DISTANCE EDUCATION

The NCEC system design generally followed the early ideas proposed by Hämäläinen, Whinston, and Vishik [1996]. The system conceptual model evolved over several years [Gordon et al, 1997, 1999; Chen and Li, 2000] and is now based on the four-layer model as shown in Figure 1.

1. The *Data Transmission Services Layer* consists of current China Internet services and other broadband and analog data transmission systems (e.g., satellite data transmission, cable TV). This layer may also be restricted within a campus network depending on how the NCEC application system is customized for a university client.

2. The *Network Application Supporting Services Layer* includes:

- Security services. For example, a security audit service realizes uniform identity authentication and authorization based on role applied to different application.
- Client request management. Client request management service provides users position-transparent access to distributed application resources through setting up one or more request management centers that act as routers in the application layer.

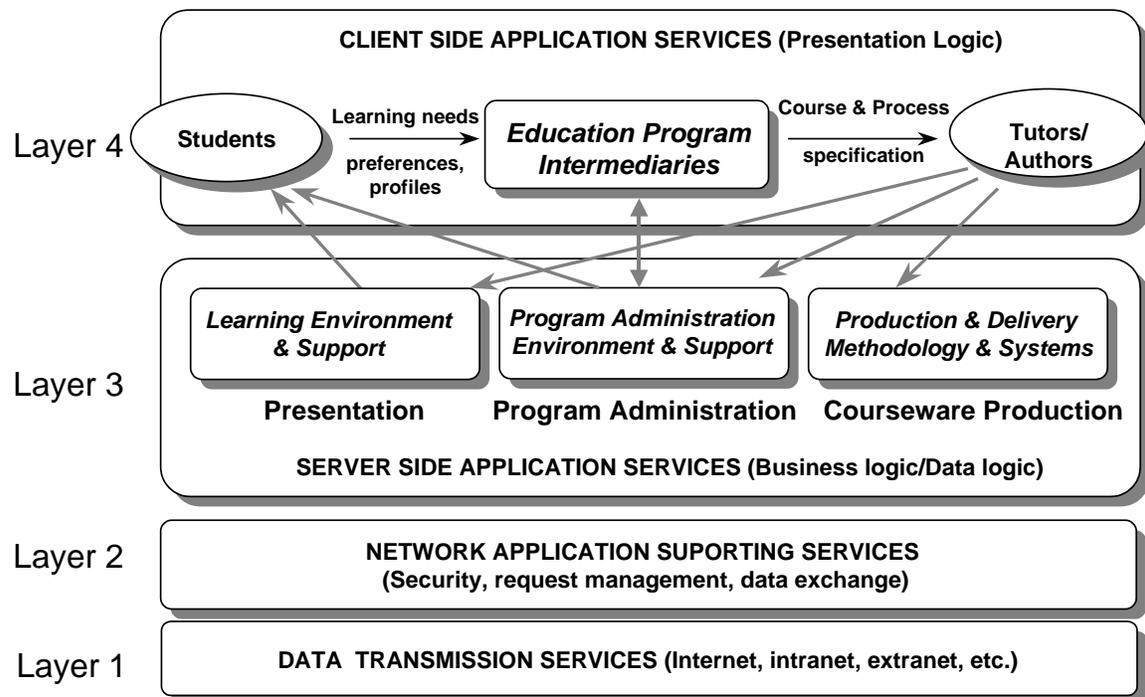


Figure 1. A Four-Layer Distance Education Model

- Universal data exchange. Data exchange service carries out a universal and reliable way for data share and exchange among different applications.

3. The *Service Side Application Services Layer* consists of the collection of tools, methods and data repositories to support three main business processes: (1) course production, (2) educational program administration and (3) distance learning.

4. The *Client Side Application Services Layer* facilitates three kinds of users' access to the distance education system: (1) students, (2) education program intermediaries, (e.g., a university or an education program broker), and (3) program/course contents providers.

### NCEC SYSTEM STRUCTURE MODEL

Figure 2 shows the three major subsystems implemented as the NCEC system at layers 1 and 2 of the four-layer model that was shown in Figure 1.

1. Courseware Authoring and Production System (CAPS),
2. Network-Based Learning Environment (NBLE), and
3. Network-Based Collaboration Environment (NBCE).

We do not discuss the educational program administration subsystem in the management information systems currently developed and operated in the universities in China. Such subsystems can be plugged in according to different administrative requirements in each university.

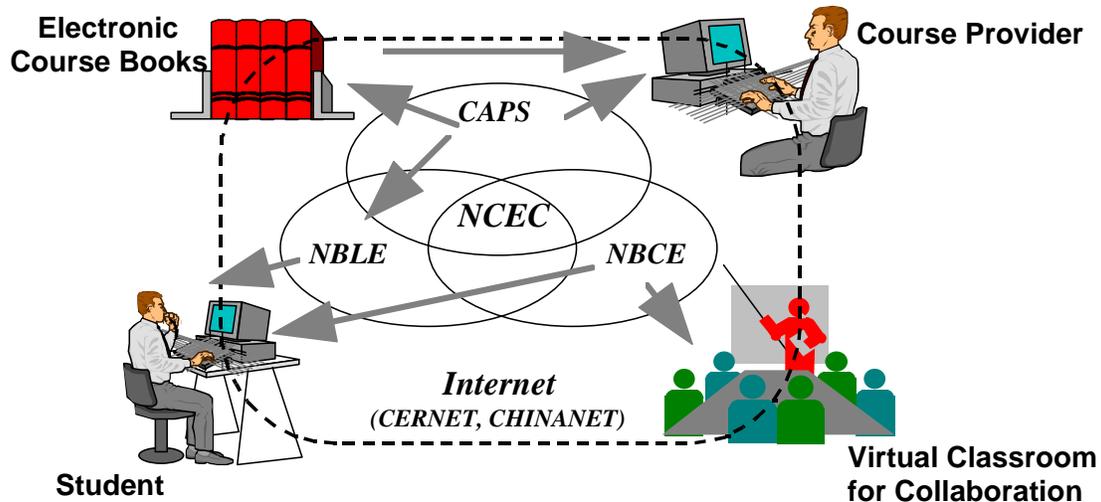


Figure 2. NCEC System Structure

### **COURSEWARE AUTHORIZING AND PRODUCTION SYSTEM (CAPS)**

CAPS supports the authoring and production process (Figure 3). It supplies users with a set of tools capable of supporting courseware development tasks such as authoring electronic textbooks, updating courseware, maintaining course element repositories, and providing other complementary elements. Courses are produced according to selected structure templates by repository. The course material repositories of reusable elements, which may be distributed on different servers and partially duplicated for local use, are accessible via the Internet.

### **NETWORK-BASED LEARNING ENVIRONMENT (NBLE)**

NBLE makes full use of the hypermedia features of the World Wide Web, providing both synchronous and asynchronous learning environments to present users with a versatile interface and deliver customizable course contents (Figure 4). Learning resources are presented as a virtual library with electronic books, which can be annotated and shared by groups of students and tutors on the network. The electronic books contain course materials, such as texts and learning tools, available either locally or remotely, customizable to the needs of groups of trainees. The virtual library contains relevant external/internal information resources linked to electronic books. NBLE includes assessment and feedback tools for self-evaluation and for instructor assessment and feedback.

### **NETWORK-BASED COLLABORATION ENVIRONMENT (NBCE)**

NBCE provides users with an integrated network-based collaborative workspace. It includes a conferencing system (in English and Chinese), a virtual classroom, a tutoring facility, and collaboration support.

Tongji University and Tsinghua University led the implementation of the NCEC system. Tongji University developed the CAPS and NBLE systems, with Tsinghua University leading the development of the NBCE system. A data interface protocol between the systems developed by Tongji and Tsinghua was established to guarantee interoperability.

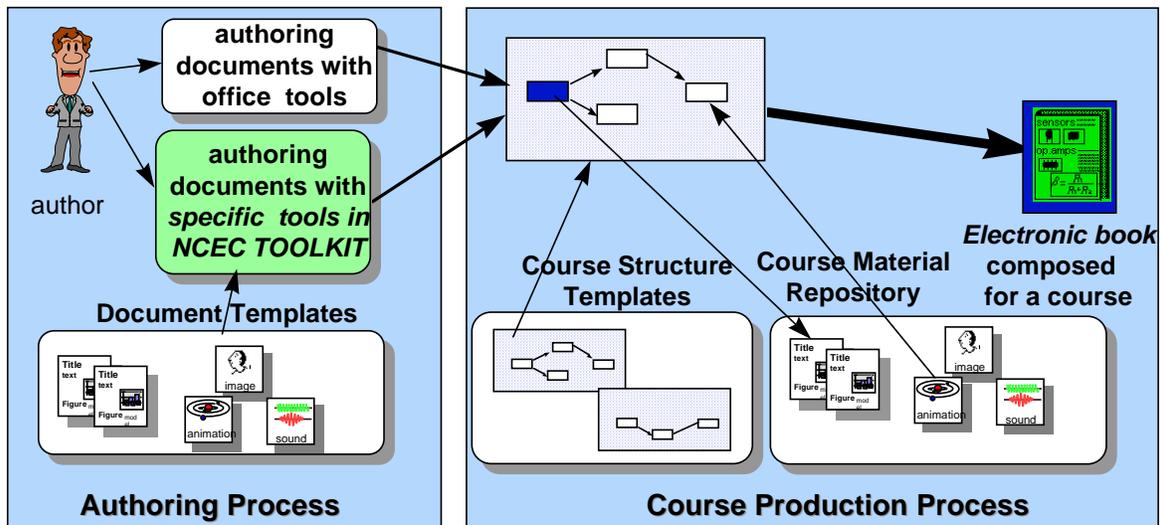


Figure 3. The Authoring and Production Process

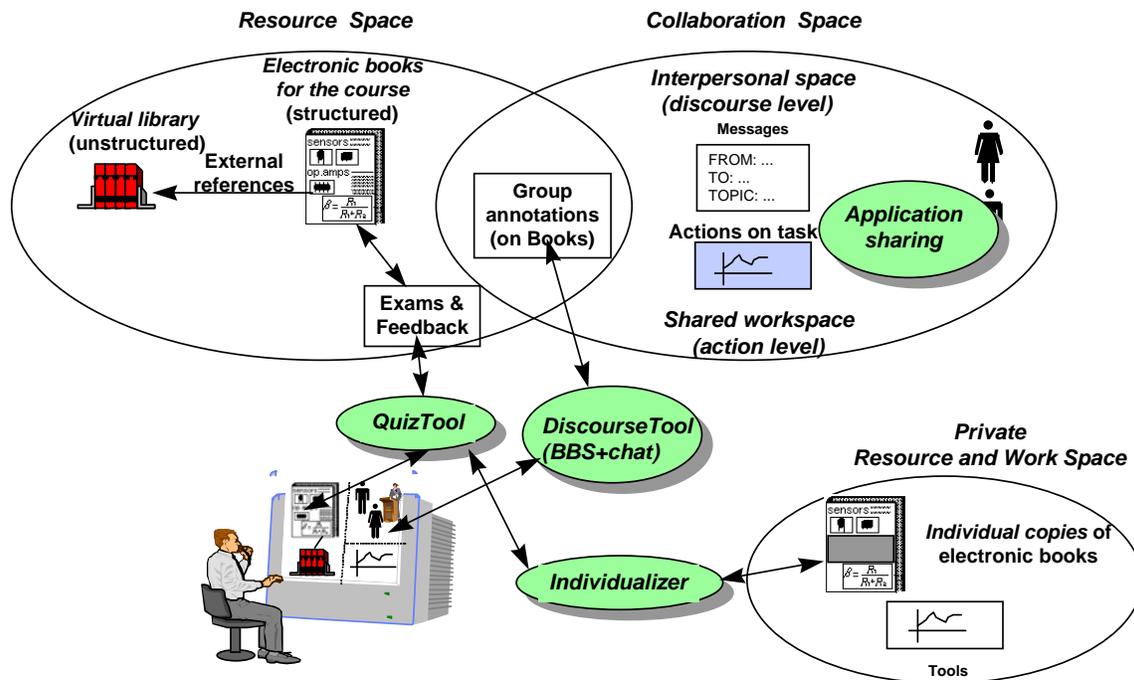


Figure 4. Network-based Learning Environment

#### IV. NCEC SYSTEM IMPLEMENTATION

The NCEC system implementation was based on the structure in Section III. The detailed design supported business and operational processes of Internet-based distance education [Yang et al, 2000; Lin et al, 2000; Li Chen and Wang, 2002]. The design was implemented in an iterative manner leading to the final design presented in this paper.

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From an implementation viewpoint, the NCEC system can be decomposed into three logical levels: (1) data storage (2) logic, application logic, and (3) presentation logic [Sandoe et al, 2001]. Following this structure, we present the implementation in the order of,

- main technical consideration,
- data modeling (data logic),
- system functional structure and major application processes application logic), and
- collaborative learning environment (presentation logic and its interactions with application logic).

### MAIN TECHNICAL CONSIDERATIONS

The NCEC project applied the results of complementary research from projects using models similar to that of the NCEC. Special techniques for Chinese information processing were used for search and retrieval, including Chinese word separation, automatic indexing of Chinese information, and Chinese information storage, transmission and display.

#### Development Platform

The NCEC system development platform adopted a web-based client/server computing architecture. Its software environment evolved through three main stages of the project development (Table 2).

Table 2: NCEC Software Environment Evolution During 1995-2002

<b>NCEC Project Stages</b>	<b>Proposal stage (1995)</b>	<b>Commencement stage (1999)</b>	<b>Completion stage (2002)</b>
<b>Operating Systems</b>	Unix	Unix/Linux, Windows NT	Unix/Linux, Windows NT/2000
<b>Web server</b>	Apache	Apache	Apache with SSL support
<b>DBMS</b>	Not decided	IBM DB2	IBM DB2 with XML Extenders, Oracle 8i
<b>Programming language</b>	Perl/CGI	Java Development Kit	Java Development Kit
<b>Markup language</b>	HTML	HTML	XML
<b>Web Browser</b>	Mosaic, Netscape	Netscape, Internet Explorer	Internet Explorer
<b>Other servers</b>	Email, FTP	Email, FTP	Email, FTP
<b>Security</b>	N/A	Password protected user authorization and authentication	The same features enhanced by the certificate authority services

Figure 5 shows the latest hardware configuration for the NCEC system development and pilot system operation.

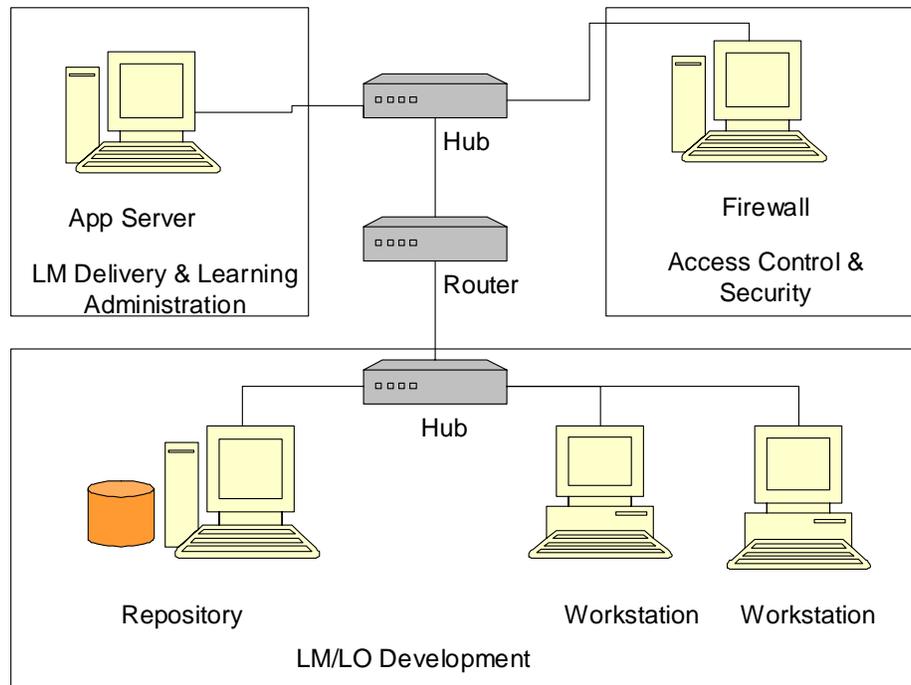


Figure 5. Hardware Configuration for the NCEC System

### Data Modeling Standard

The NCEC system is intended to provide a broad range of online services to facilitate

- individual learning and group collaboration,
- user's self-planning, self-assessment and self-regulating of learning materials and learning processes.

We adopted meta-data modeling, i.e. LOM (Learning Object Metadata) defined in XML (eXtensible Markup Language), for NCEC courseware data modeling. The application of meta-data modeling standard allows the NCEC system to deliver highly individualized features to satisfy diversified user needs with reusable learning components. The NCEC system applies mainly server-side technology like Java servlets, JSP, and XSP (eXtensible Server Pages), and uses revised OMT and UML methodology in system analysis and design. In the systems implementation and programming, Java technologies including RMI, JDBC, EJB, and JMS are used. NCEC also includes the components to support system deployment and exploitation.

### Chinese Information Processing

NCEC applications are both Chinese and English language enabled. The application requirements in Chinese are not only for the language, but also for pedagogical needs, which are rooted in cultural and societal differences between Chinese and western language speakers. Chinese information processing—input, indexing, tagging, and displaying—brings three specific challenges:

- the encoding of Chinese characters,
- the platform of Chinese information input/output, and
- the techniques of separating and automatic indexing Chinese words.

The three most common Chinese character-encoding sets are GB2312-1980 (the National Standard of the People's Republic of China), Big5 (used in Taiwan and Hong Kong), and Unicode (which encodes about 21,000 simplified and traditional characters). Adopting these Chinese character encoding schemas automatically suggests that both Chinese Microsoft Windows (95/98/NT/2000) and Linux with a Chinese interface are preferable.<sup>7</sup> Other Chinese shell software programs are also able to process Chinese characters coded in GB or BIG5. For example, RichWin and NJ Star are popular in supporting web browsers such as IE 4.0 (or later version) and Netscape 4.7x. IE with a Microsoft Windows supported Chinese font set is more stable than Netscape and is widely accepted by Chinese users. Other Unix compatible software installed with the Chinese font set are also recommended.

Chinese word separation is a special technical issue in Chinese information input and indexing [Wu and Tseng, 1995; Lam et al, 2001]. Because the LOM schema and XML-based data modeling approach [Anderson, 1999; IEEE, 2003 and 2004; ISM, 2001a, 2001b; Kunzler, 2002] were adopted as the basic documentation standard, manual Chinese text tagging in accordance with predefined DTD (Document Type Definition) files became our basic approach. However, to convert existing Chinese text files into courseware repository elements, automatic Chinese word separation is also needed and is to be implemented in the future.

### **COURSEWARE DATA MODELING**

The NCEC data model is shown in Figure 6. The critical portion of the model is the courseware data module on the right-hand side. Other relevant data modules, such as examinations, curricula, and user accounts, are built into the courseware data modules.

The course data model is structured hierarchically top-down: degree program, course, learning material (LM), and learning objects (LO), where an LO is an elemental pedagogical unit, and an LM is an online textbook dynamically generated from LOs. That is, an online electronic version of a textbook is logically an LM containing multiple LOs.

Both LMs and LOs are predefined in templates. A presentation of LM is actually a higher level of template linked to a combination of lower-level templates related to different LOs. Each textbook is allowed more than one static template in the form of XML. The presentation style of the LM is defined by XSL (eXtensive Stylesheet Language). An LM will be translated into displayable HTML form by the XML processor incorporated in the Web server at run-time.

### **SYSTEM FUNCTIONAL STRUCTURE AND MAJOR APPLICATION PROCESSES**

The NCEC system functional structure (Figure 7) is the major portion of the overall design [Yang, Li and Lin, 2000]. The structure covers all functions for CAPS and NBLE and some functions for NBCE, and consists of the following seven modules:

- Learning Object Authoring
- User Accessing
- User Management
- Learning Administration
- Learning Material Composing
- Repository Accessing
- Query Parsing

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<sup>7</sup> Linux appears to be a suitable platform for Chinese applications. Specifically, the Chinese government is subsidizing Red-flag Linux, a Chinese native product, to offset the monopoly power of Microsoft Windows in China's software market [Li, Lin and Xia 2003].

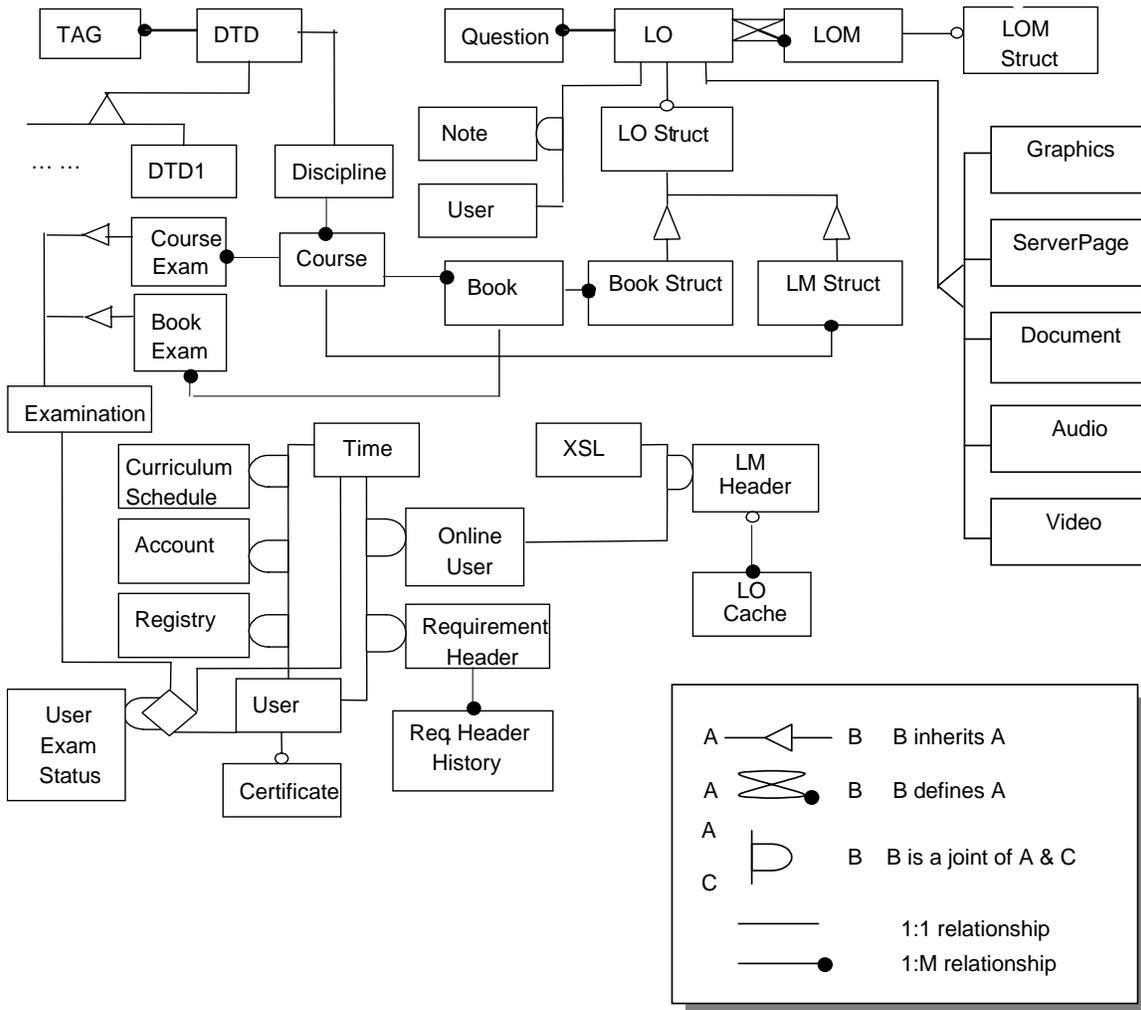


Figure 6. NCEC Data Model

These modules support two major processes at the application logic layer: courseware production and courseware exploitation.

**Courseware Production**

Courseware production is the main process in CAPS, which is underpinned by three modules: LM Composing, Query Parsing, and Repository Accessing [Yang, Li and Lin 2000; Wang, Li and Chen, 2002]. It provides functional supports for the following five-step process:

- Defining tags and the associated DTD files, which are building blocks for LOs.
- Parsing textbooks into LOs. This step converts regular text files into LOs in XML.
- Designing LM presentation styles by combining related LOs and XSLs.
- Validating XML forms in order to correct any possible errors.
- Creating textbook template according to the logic structure of the textbook to be delivered.

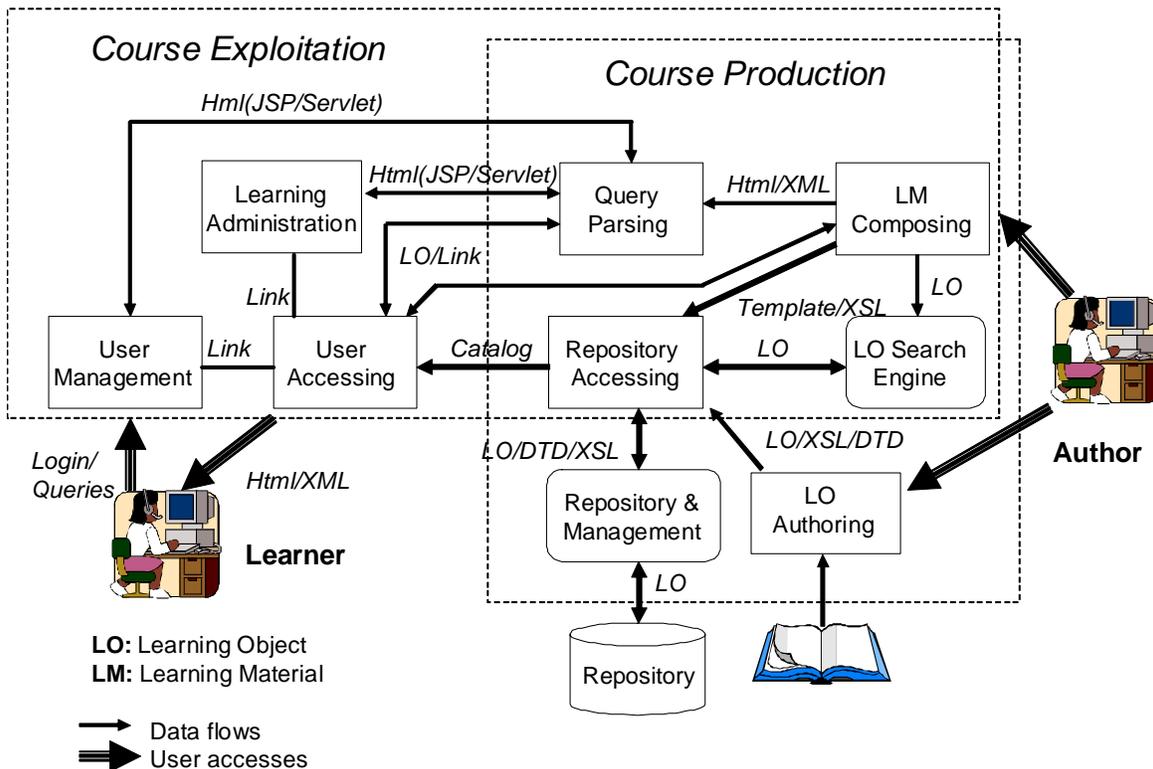


Figure 7. A Function Model for the NCEC System

### Courseware Exploitation

Courseware exploitation consists of two sub-processes: (1) Learning Material Delivery and (2) Learning Process Management.

Learning material delivery is supported by four modules:

- User Accessing,
- LM Composing,
- LO Search Engine and
- Repository Accessing.

These modules allow users to access online course materials that are dynamically generated from the NCEC courseware repository.

Learning Process Management is supported by two subsystems: (1) User Management and (2) Learning Administration. The User Management System provides functions such as user registration, system logon, user authentication, and account services. The Learning Administration System allows registered users to obtain services such as searches, examinations, and curriculum creation (teacher use only).

Because courseware exploitation falls into the scope of the Network-Based Learning Environment (NBLE) and is closely relevant to the user interface design, its implementation is presented in the next subsection in more details.

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## COLLABORATIVE LEARNING ENVIRONMENT DESIGN AND IMPLEMENTATION

Collaborative learning environment design is focused on the learning user interface and interaction design. Its implementation is based on a pilot collaborative learning system, KWAUFU<sup>8</sup>, developed by Tsinghua University in 1998 [Li, Geng and Li, 1998; Li and Li, 2000] (Figure 8).

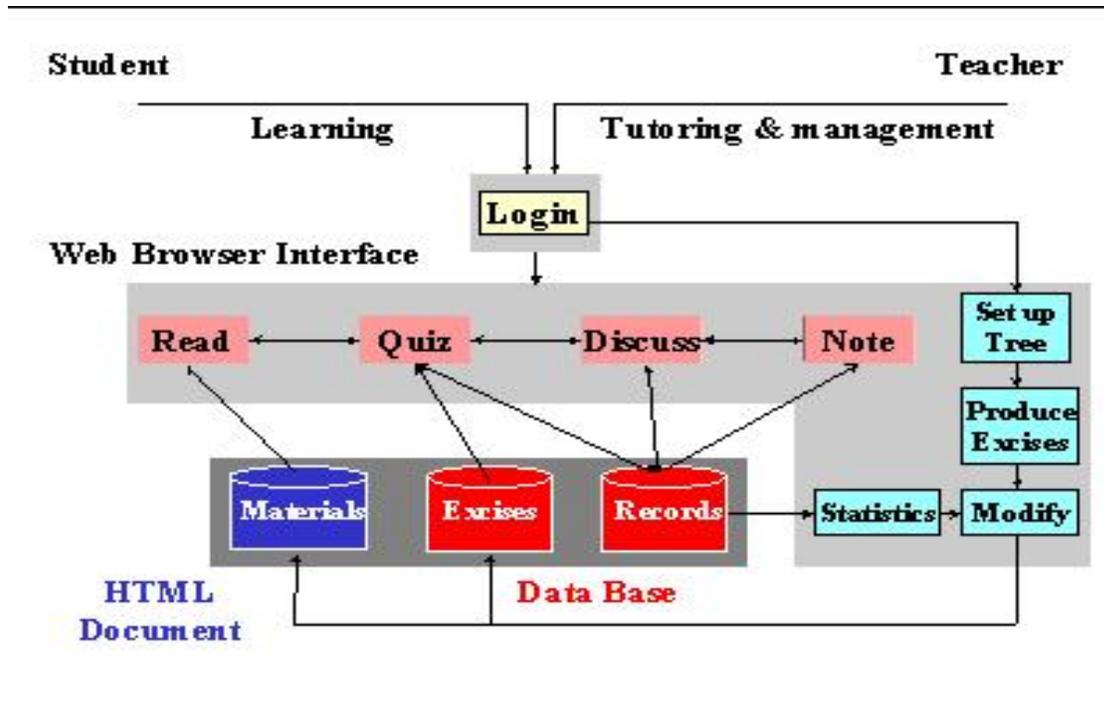


Figure 8. KWAUFU's structure

KWAUFU offers individualized learning on demand. Learning materials can be customized to meet students' qualifications and needs. Students can access utilities, such as bookmarks and notes, to help construct personalized knowledge during their study. They can take advantage of synchronous or asynchronous means, such as chat, e-mail, and forums, to communicate with teachers or other students. A self-help test facility is available for students. Both NBLE and NBCE rely heavily on the implementation of a user interface possessing the same features and functions as KWAUFU. As a result, KWAUFU can be conveniently upgraded and integrated to the collaborative learning environment implementation, the common part of NBLE and NBCE.

The collaborative learning environment for NCEC consists of the following three subsystems:

- User-Oriented Courseware Access System (UOCAS)
- Network-Based Collaboration Environment (NBCE)
- Learner Management System (LMS)

### User-Oriented Courseware Access System (UOCAS)

UOCAS (Figure 9) provides three functions with the modules depicted in Figure 7 [Li et al, 2002]:

- LM Customization, which allows learners to customize their textbook dynamically according to their needs.

<sup>8</sup> KWAUFU is a name for an ancient Chinese man in a Chinese myth who chased the sun.

- LM Access, a user-friendly interface for LM browsing, annotating, and quiz taking. These items are functions of the Network-Based Learning Environment (NBLE).
- Behavior Recorder, which saves student's behaviors and learning processes in log files to provide original data for pedagogical analyses.

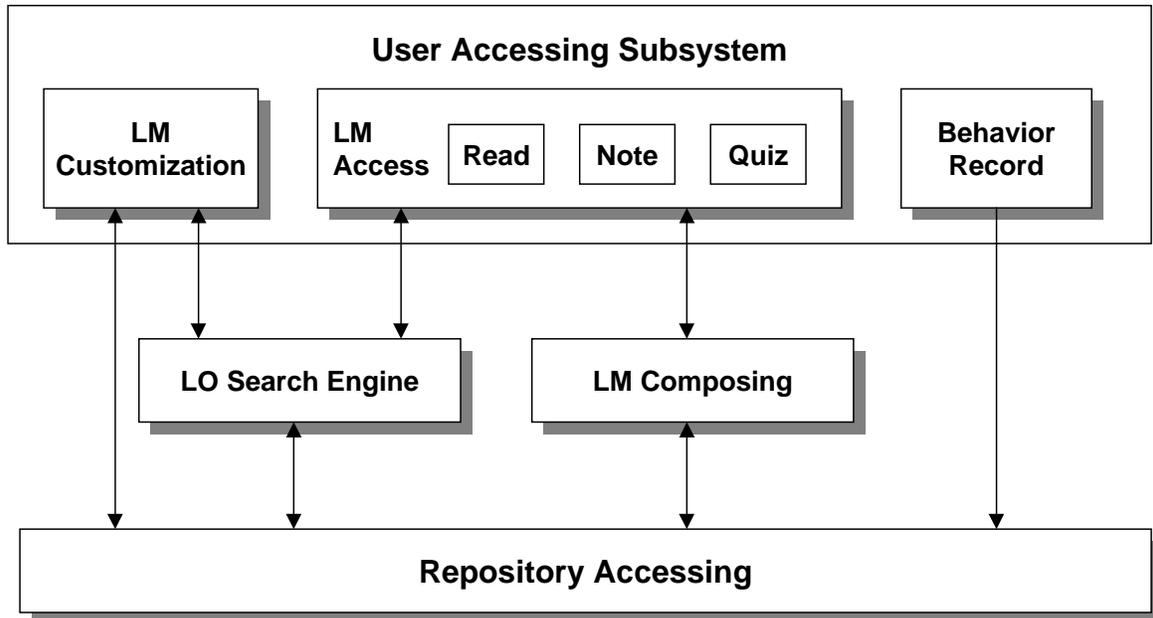


Figure 9. Interfacing UOCAS to other systems

Figure 10 shows a main menu of courses retrieved by UOCAS.



Figure 10. A Screenshot for the Menu of UOCAS Utilities

### **Network-Based Collaboration Environment (NBCE)**

Two collaborative modes are considered for NBCE: asynchronous and synchronous. NBCE provides facilities such as bulletin board, topic discussion area, essence area, and internal email service in the asynchronous mode. In the synchronous mode, students can exchange messages in real-time. The basic functions available in NBCE are online discussions and instant messaging<sup>9</sup>

### **LEARNER MANAGEMENT SYSTEM (LMS)**

LMS calls two major modules: (1) User Management, which is used for system access authorization and authentication, and Learning Administration, which is mainly a transaction logging and recording system.

### **QUALITY CONTROL AND PROJECT MANAGEMENT**

Since NCEC is a multi-national and multi-cultural project, quality control became a challenging problem in project management. Issues of quality control for the NCEC project included

- the compatibility of the software products developed by different partners,
- the software and data standards adopted,
- the project documentation, and
- the coordination of distributed teamwork.

Therefore, it was necessary for us to develop a management structure, which could handle two discrete teams, one in the EU and the other in China. In addition to developing a project management structure it was necessary to interface to the EU structures.

The quality management system for development, production, and delivery of course materials was designed and implemented by the University of Paisley. Tools were designed to assist in the construction of learning objects to enhance lesson quality. A documentation and report system was established to facilitate managerial information exchange and project monitoring. By applying quality management and control on given tools, the project was made more cost effective and efficient. A further advantage of this approach to quality was that scheduled quality reviews were held at suitably agreed intervals. Such reviews were specific to the particular product being assessed, and comprised of the following:

- peer assessment review,
- walkthroughs,
- testing , and
- internal reports such as teleconferencing.

The management structure of NCEC is shown in Figure 11.

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<sup>9</sup> Extended from the NCEC project, Tsinghua University implemented a videoconferencing based virtual classroom for another distance learning project (China's 863 Research Program, Project#: 863-317-01-04-99) [Li, Chen and Zhu, 2001]. Since this capability was not planned for the NCEC, we do not present the details in this paper.

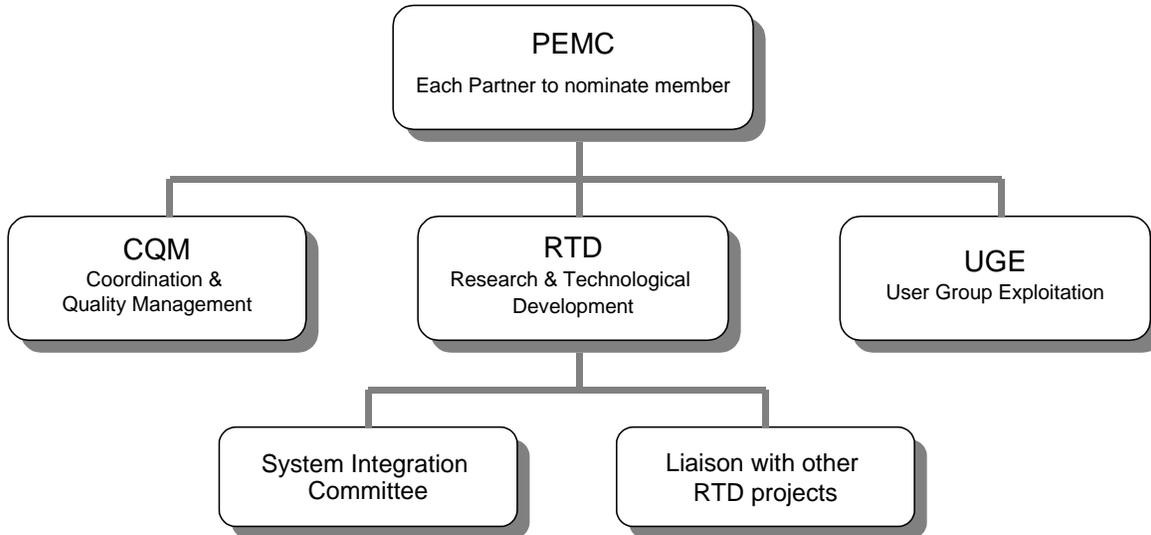


Figure 11. NCEC Project Management Structure

The Project Executive Management Committee (PEMC) shown in Figure 11 was the executive for the quality management system, and was formed with a representative from each partner. The mission of the PEMC was to coordinate the progress of the research consortium across the six partners (Section I) and monitor the progress of the project, so that the targets of the research were assured.

The University of Paisley acted as the coordinator for overall quality management and financial control (in charge of CQM). Tongji University took responsibility for the scientific coordination and leadership of the project (in charge of System Integration Committee under RTD) and EVITech led the liaison with other RTD Projects. Tongji University was also responsible for User Groups and Exploitation. Day-to-day management of the project involved two components representing the two geographical areas involved. In the EU, one member of the staff acted as local coordinator. In China, Tongji University was appointed as a local coordinator. In each case, the scientific coordinator and the two local coordinators report to the PEMC.

NCEC system development was coordinated at two levels in the project management structure. A small group consisting of the project executives from Chinese and European partners was in charge of the overall system design. This group proposed the initial system and the project development plan. After the general design of the system was done, partners in the NCEC project worked separately in accordance with the general technical scheme and work plan. European partners were responsible for the advanced technology research. Tongji University and Tsinghua University were the main project developers for detailed system design and implementation. FEIC and NSDRG fulfilled a few technical modules of the system following Tongji and Tsinghua's guidelines.

System Integration was the responsibility of Tongji University who had to ensure:

- the interoperability of all components.
- that all development partners used the correct version of API for each of the tools.
- that the individual components were of a high quality,
- that the components interrelated in a consistent and reliable fashion.

We established effective communications by using an auditable electronic mail system supported by computer conferencing.

## V. EXPLOITATION OF THE NCEC SYSTEM

### PILOT APPLICATIONS DURING NCEC PROJECT DEVELOPMENT

Pilot applications of the NCEC system during project development were mainly aimed at testing the usability of the system. A number of pilot courses were developed in 1999 for verification of the NCEC methods and tools. The pilot courses were carried out as training experiments, where both the cost-efficiency of the production methods and the effectiveness of learning in terms of learning outcomes were assessed. The end user courses were in the areas of engineering and information technology, including,

- Introduction to Telecommunications Networks
- Internet Technology
- Electronic Documents and Network Publishing

The telecommunications course was intended to provide competencies and skills required by workers for both fixed and mobile telecommunications networks and the functions of different network elements. The objective of the Electronic Documents and Network Publishing course was to provide knowledge and skills for the production, publishing and management of electronic documents. The experimental techniques were based on those developed within other EU and Chinese projects, with evaluation being carried out as established in other EU projects.

In 2000, the Chinese partners started to develop a number of pilot courses in Chinese. Fujian Economic Information Center ported its CD-versioned *Confucius* to the web-based version that can be used as a supplemental material for a course in Chinese literature. This web-based version is available in both English and Chinese [Lin et al 2000].

Tsinghua's NCEC project team developed two digital textbooks for the KWFU system. One is *Introduction to the Internet* and the other is *Computer Networks*. Both were used for practical courses lectured in Tsinghua University. Although the two authoring tasks were not sponsored by NCEC, they were implemented in the NCEC environment.

### POST-PROJECT EXPLOITATION

Post-project exploitation is of strategic importance in realizing and increasing the value of the NCEC system. In late 2001, after the project team completed the development of the NCEC system, the project's participant institutions reached an agreement that authorized the exploitation of NCEC products to all partners in all forms. The partners were assigned the following tasks:

- Tsinghua University and Tongji University were to popularize the application of the NCEC system among non-profit educational institutions;
- NSDRC and FEIC were responsible for commercializing NCEC applications in business; and
- University of Paisley and EVITech were to explore business potentials of the NCEC system outside of China.

Two main routes were used for NCEC system exploitation.

1. Exploitation of the technology by setting up a China-side broker. The NSDRC spin-off company (Beijing Creative Century Information Technology Co Ltd) was given the exploitation rights to NCEC technology. It should be in a position to act as a localization broker for Western education and training services and products.

2. Through the network of partners. On both sides of the world, clear opportunities exist within the developing e-Learning marketplace, both in the public and private sectors. The exploitation plan places emphasis on the following aspects:

- Extending NCEC system to other distance education programs in China.
- Setting up joint distance education programs between European and Chinese universities. These joint programs can be a transfer of the programs in one partner country to another. The applications are also transferable to other countries.

Since September 2003, Tongji University has been working with Manheim University, Germany, on a distance education program based on NCEC's distance education technology. The two universities will mutually deliver courses in information technology and information systems for undergraduate students in the business school of the other university. In the first phase, a prototype point-to-point video conferencing system will be implemented for the real time video transfer between the two universities. In the second phase a complete distance learning system developed by Tongji University will be in operation. Tongji University's experience in the NCEC project was the key factor in reaching the agreement on the project.

## VI. IMPACTS OF NCEC PROJECT

The significance of the NCEC project is not only in its direct application on distance education in China but also in its impacts on China's Internet application development and technology adoptions. NCEC is seen as a seed project with crossover effects on other projects. While the NCEC project was in progress, more and more Chinese institutions started research projects involving distance education systems. The NCEC project was no longer the largest such project in funding and scope.

The relation of the objectives and the impacts of the NCEC project are shown in Figure 12. The project's effects are significant, because it was the first distance-education project proposed in China and carried out jointly there by Internet application researchers. It involved China's major Internet services and European institutions with successful experiences in this field. Most important, the NCEC project impacted China's CERNET construction and applications significantly because of its objectives (Figure 12), which is far beyond our original expectation. This outcome is mainly the result of the involvement of NRC, Tsinghua University, since 1997.

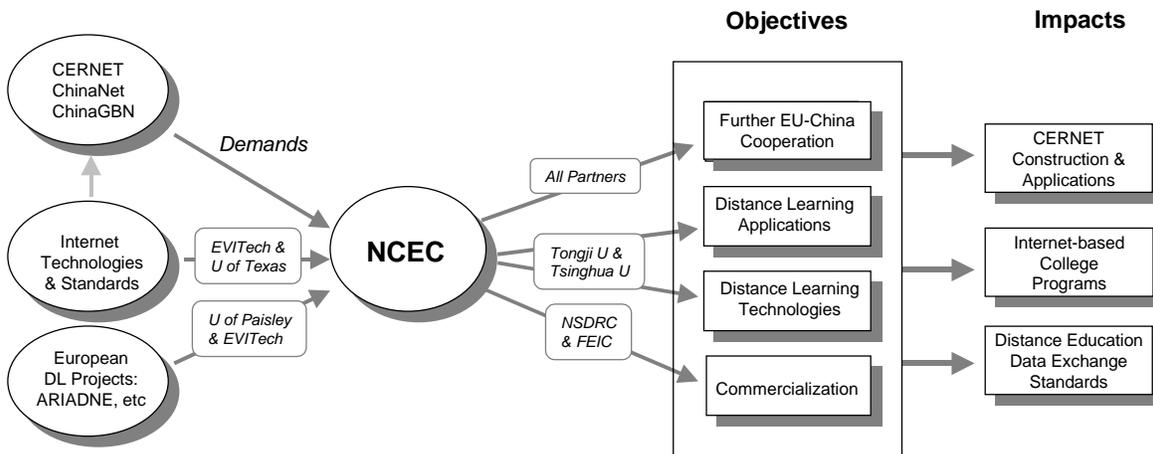


Figure 12. The Impacts of NCEC Project<sup>10</sup>

<sup>10</sup> The Center for Information Systems Management (CISM) at The University of Texas at Austin, was on the advisory board of the NCEC project during 1994-1997, because of its leading role in distance education research (Hämäläinen, Whinston and Vishik, 1996)

NRC of Tsinghua University is the designer and operator of CERNET. It played the key role in adopting NCEC outcomes to CERNET and feeding back the requirements from CERNET and its users for the distance education system. The mechanism worked in the following four steps:

- Identifying the value of outcomes from NCEC project in certain periods;
- Applying them to the relevant technology research projects which provided the information for the decisions on CERNET development issues;
- Obtaining the needed decision-making information for CERNET from the technology research projects; and
- Informing the needs and demands from CERNET to the NCEC project.

We witnessed the following effects of the NCEC project:

- During 1995–1999, several distance education projects in China were carried out in light of the ideas from NCEC project. For example, the Network Research Center of Tsinghua University started a pilot distance education research project in 1997 sponsored by the Focal Research Projects in the Ninth Five-year Plan [Li and Weng, 1998; Zhu and Li, 1999]. A distance education system with TV and Web technology was developed and tested [Li, Geng and Li, 1998; Li and Weng, 1998]. In 2001, Tsinghua University launched a generic distance education project called: “Demonstrative Multimedia Distance Education System on the High-speed IP Network in China (DMDES)”<sup>11</sup> The objective of the project was to build virtual classrooms available on the 155Mbps CERNET backbone to provide electronic courses to the universities participating in the pilot operation. Additional distance education projects triggered by NCEC are listed in Table 3.

Table 3: Main Follow-up Distance Education Projects in China

No:	Project Name	Time Frame	Description
1	The Application of Television Techniques in Distance Education	September 1996-August 1998	The project proposed the technical architecture for an Internet-based distance education system reinforced by TV technology [Li, Chen and Zhu, 2001]
2	Demonstrative Multimedia Distance Education System on the High-speed IP Network in China	August 1999-December 2000	One of China's “863” projects. It is a multimedia distance education system based on the high-speed IP network [Li and Zhang, 2002].
3	Distance Education System in Innovative High-speed Network	January 2000-February 2002	One of China's “985” projects.
4	Intelligent, Standardized, and Open Distance Education System Architecture	January 2000-December 2001	This project is sponsored by China's Natural Science Foundation. It is aimed at more theoretical study to improve the acceptability and scalability of distance education systems [Li et al., 2002].
5	Key Network Technology for Distance Education	December 2001-December 2002	This sub-project of Modern Distance Education Engineering is sponsored by China's Ministry of Education [Wang, Li and Chen, 2002].

<sup>11</sup> Project#: 863-317-01-04-99 sponsored by China's Ministry of Science and Technology.

- The applications listed in Table 3 stimulated the demand for better network service quality and promoted the construction of a series of Internet backbone projects (Table 4).

Table 4. CERNET Networking Projects for Distance Education

No:	Project Name	Time Frame	Descriptions
1	Internet Key Application Technology Research	October 1996-December 1998	Distance education system is the major tested project.
2	CERNET Backbone Upgrade	March 1998-April 1999	The network backbone was upgraded to 2 Mbps in support of distance education system operation.
3	Public Service System Architecture for the Higher Education (One of "211" Engineering Project)	November 1998-July 2001	This is CERNET's information service system architecture that provides the networking capacity for majority of Chinese universities. It has been one of the most important information infrastructures for education and research.
4	CERNET High speed Backbone for the Modern Distance Education	September 1999-December 2001	The project adopted DWDM/SDH technology and provided high-speed network services with up to 40 Gbps capacity and total 20,000 km fiber optic connections. The project allows CERNET operating at 2.5 Gbps. 100 universities have connected to this network with 100-1,000Mbps bandwidth by 2003. This is an important infrastructural project for distance education.

- With the pioneer work done by the NCEC project, the standardization of distance learning techniques was accepted in China. In 2002, China's Distance Learning Technical Standard (DLTS) organization officially released "Technical Standard System for Modern Distance Learning and Eleven ad hoc Standards, v1.0" [MOE 2002a] to promote the adoption of the standards for Internet-based applications, which have been widely accepted internationally.

The standards include the following documents [MOE 2002b]:

- CELTS-1 System framework and the reference models
- CELTS-2 Glossary and terminology
- CELTS-3 Learning object metadata
- CELTS-9 Content encapsulation
- CELTS-10 Exercising and testing operations
- CELTS-11 The learner model
- CELTS-13 Student identification certification
- CELTS-14 Learning ability definition
- CELTS-17 Platform and media reference

CELTS-20 Computer-based instruction

CELTS-31 Technical standards for educational resources

With the experience in the NCEC project, NRC of Tsinghua University became an active participant in the standards development process.

Because distance education technology matured and the Internet became widely available, China's Ministry of Education approved sixty-seven "Network Universities" – the Internet-based distance education universities [China Education Online, 2002]. Thus distance education moved from research to practice. The practice of distance education is expected to raise new research topics and demand for better Internet-based applications.

Figure 13 shows the relationships among CERNET construction, the NCEC project, China's distance education technology research, and technical standardization for distance learning. Referring to the milestones of NCEC and CERNET, the diagram illustrates the relationships among components in different categories.

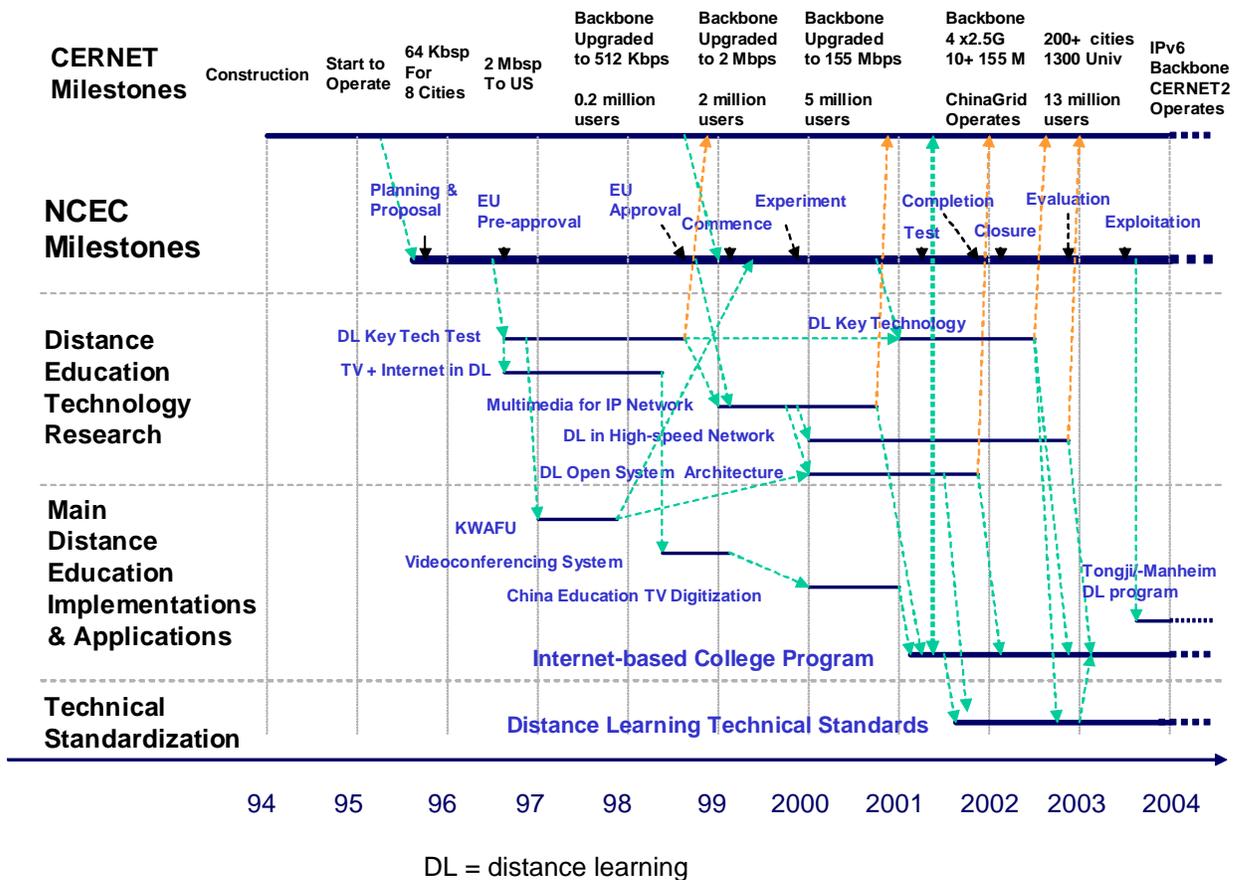


Figure 13. Relationship between NCEC and Other Projects

Roughly, the relationship chain is: CERNET -> NCEC Project -> Technology Research-> Implementations and Applications -> Technical Standardization. The rationale is that the availability of CERNET and the needs to the realization of its value were the original driving force of the NCEC project. The NCEC project pushed forward the research in distance education application technology and the implementation of applications, and finally the standardization of distance learning. We can see that there is no direct effect from NCEC to CERNET, but there are several feedback loops from the application projects to CERNET evolution, implying the indirect

effects from the NCEC project to CERNET. Specifically, the Internet-based college program as the comprehensive application of distance education technology had mutual effects with CERNET expansion and upgrade.

In our judgment, NCEC is a successful pilot distance education system project. It reached its planned goals, met majority short-term objectives, and affected other more important projects in China's Internet construction and application. In particular, the NCEC project impacted China's CERNET evolution significantly. CERNET followed the educational requirements set forth mainly by Internet-based distance education [Chen and Li, 2000; Li and Li, 2000; Li, Chen and Wang, 2002; Li, Geng and Li, 1998; Li, Chen and Zhu, 2001; Li et al, 2002; Li and Zhang, 2002; Wang, Li and Chen, 2002].

## VII. CONCLUSIONS

In this article we introduced the NCEC project's background, system design, current status, development management, and its impacts on other relevant projects. The NCEC practices since 1995 show that:

- It is possible to implement learning object metadata (LOM) in a Chinese context
- It is possible to develop learning systems in a cross-cultural environment.
- It is possible to develop a learning system which is capable of servicing the needs of the Chinese population.
- It is possible to develop interoperable standards across Latin and Chinese languages.

Several special characteristics differentiate the NCEC project from other information system research or application projects.

1. It was carried out by six institutions distributed in five cities geographically located in two continents.

2. Its lifecycle was long

- three year to refine the proposal and get it approved,
- one year for project "warming-up", and
- three more years for project development.

3. Its major objective was not merely application development or technical research beneficial to a few participants, but included promoting the adoption of advance technology in China's education system with a demonstrative software and the further scientific and technological cooperation between China and the European Union.

4. The NCEC project exerted strong influence on other distance education projects in China and influenced the growth and evolution of CERNET. Therefore, more emphases is placed on the intangible outcomes:

- the closer relationship between China and Europe in Internet application technology exchange,
- a more skillful consortium in China for distance education system development, and
- the lessons and experience learned during the project development.

For educational institutions, as well as for European and Chinese companies, such a network-based training system as the NCEC system forms a basis for the development of joint courses and training systems for industries (both in competence development and in customer training). The NCEC system can be used effectively as a model for collaboration in research and development projects. The collaborative project between European and Chinese institutions enabled all the partners to contribute and share the expertise required to address the specific issues of Chinese information processing and the telecommunications and computing environments. By providing a focused research and development effort on network-based methods and tools in continuing and distance education in China, we view the NCEC project as being one of the relevant contributors to the rapid development of Internet in China.

We realize that there is still much to be done in NCEC system exploitation. Although the NCEC system adopted advanced information technology, many current distance education systems operating in China are still based on primitive technology, for example, HTML-based rather than XML-based online course materials. A gap still exists between what NCEC can do and the portions of NCEC project that have been adopted. The NCEC system only provides a general set of functions based on some key techniques. Thus, adopters of the NCEC system need to customize and expand these NCEC core techniques and functions further. Requirements need to change continually to keep pace with information technology advances and social-economic environment evolution. How the advanced technology provided by the NCEC system can be added coherently into existing educational programs and administrative system remains open to each adopter. This issue is more social behavioral than technical. The NCEC project can serve as a case for further research. Nevertheless, the impacts of the NCEC project on other distance education projects that further influenced CERNET's evolution added to the success of NCEC project.

*Editor's Note:* This article was received on February 12, 2004 and was published on August 3, 2004.

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1. these links existed as of the date of publication but are not guaranteed to be working thereafter.
2. the contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
3. the authors of the Web pages, not CAIS, are responsible for the accuracy of their content.
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**APPENDIX I: A TIMELINE OF CHINA'S DISTANCE EDUCATION**

- August 1995 - NCEC was proposed to European Union as a joint-research project between China and Europe;
- 1996 - Tsinghua University called for the adoption of Internet-based distance education;
- 1997 - Hunan University, in cooperating with Hunan Telecom, established China's first on-line university;
- 1998 - Tsinghua University launched online master programs;
- September 1998 - China's Ministry of Education officially entitled Tsinghua University, Beijing University of Post and Telecommunications, Zhejiang University, and Hunan University as the pioneer educational institutions in pilot distance education programs;
- 1999 - Ministry of Education promulgated the *Comments on Developing Advanced Distance Learning in China* [ChinaGate, 2004], which expatiates the guidelines, aims and tasks of distance education in China;
- August 1999 - Beijing University and the Central Broadcast and TV University were added to the pioneer list for Internet-based distance education;
- September 1999 - *CERNET High-speed Backbone Project* [NRC, 2004b] was approved;
- July 2000 - Ministry of Education released the *Provisional Administration Methods for Educational Website and On-line Schools* [ChinaGate, 2004], exhibiting the jurisdiction of the Ministry over educational websites and Internet-based schools;
- Later in 2000 - The Ministry of Education granted the distance education licenses to Tsinghua and another 14 universities, and expanded the pioneer list to include 31 universities and colleges; then the Ministry promulgated the *Several Comments on Supporting Some Universities and Colleges to Set up Internet Education Schools and Pioneer Distance Education* [ChinaGate, 2004].
- July 31 2000 - The 31 pioneers in the distance education assembled a consortium called *Coordination Team for Advanced Distance Learning in Higher Education*, aiming at enhancing inter-pioneer communication and cooperation and facilitating exploitation and sharing of educational resources [ChinaGate, 2004];
- September 2000 - Some pioneers kicked off their on-line campus programs;
- October 31 2000 - *China Advanced Distance Learning Satellite Broadband Multimedia Transmission Platform* came into operation [Li and Zhang, 2002], allowing simultaneous transmission of decades of video and multimedia channels at different rates; and the Internet access service provisioned on the platform enables high-speed interconnection with CERNET, forming a satellite-land consolidated bi-directional education network;
- 2000 - According to the Ministry of Education, the 31 pioneer universities in online distance education offered seats to nearly 190,000 registrants, most of whom are destined to degree programs [NRC, 2004d].
- Fall 2001 - The number of registered students in eLearning system reaches 400,000, according to Ministry of Education of China [NRC, 2004d].
- January 2002 - NCEC Project was completed and evaluated by EU in Luxemburg.
- August 2003 – A distance education system is deployed to Lhasa, the capital of Tibet, which is the least developed rural area in China [Zhong, 2003].
- 2003 – 67 Internet-based distance education colleges are in operation [China Education Online, 2003].

## APPENDIX II: STATUS OF CHINA'S EDUCATION SYSTEM IN THE 1990'S

China's education system [MOE, 2000] is composed of 4 subsystems, basic education, occupational/polytechnic education, common higher education, and adult education:

1. Basic education consists of pre-school education, primary (6 years) and junior (3 years) and senior (3 years) schooling. The 1999 statistical data show:
  - 582,300 primary schools countrywide with an enrollment of 136 million;
  - 64,400 common junior middle schools nationwide with admission of 22 million and enrollment of 58 million;
  - 14,100 common high schools nationwide with admission of about 4 million and enrollment of 10.5 million.
  
2. Occupational/polytechnic education consists mainly of medium-level professional schools, polytechnic schools, occupational middle schools, and short-term occupational and technical training programs of various forms. In 1999, the data for these schools were:
  - 3,962 secondary technical schools with an enrollment of 5,155,000.
  - 8,317 vocational senior middle schools with admission of 1,603,800 and enrollment of 4,438,400;
  - 4,098 polytechnic schools with admission of 515,500 and enrollment of 1,560,500.
  
3. Common higher education comprises of junior college, bachelor, master and doctoral degree programs. Junior college program usually last 2~3 years; bachelor program 4 years (medical and some engineering and technical programs, 5 years); masters program 2~3 years; and doctoral program 3 years. By 1999, there were 1,071 common colleges and universities offering
  - 2,754,500 seats to those applying for junior college and bachelor programs,
  - 19,900 seats to those applying for doctoral programs
  - 72,300 seats to master program applicants,

They accommodated 54,000 doctoral candidates and 179,500 master candidates.
  
4. China's adult education consists of schooling education, anti-illiteracy education and other programs oriented to adult groups. Up to 1999, 871 colleges and universities were dedicated to adult education and some 800 correspondence-based and evening adult education programs were launched by common colleges. They offered 1,157,700 seats to those pursuing junior college and bachelor programs, and granted diplomas to 888,200 people.

Figure A-1 shows the admission rate changes in the 1990s in different level of education institutions; Figure A-2 shows their enrolment growth in the same period.

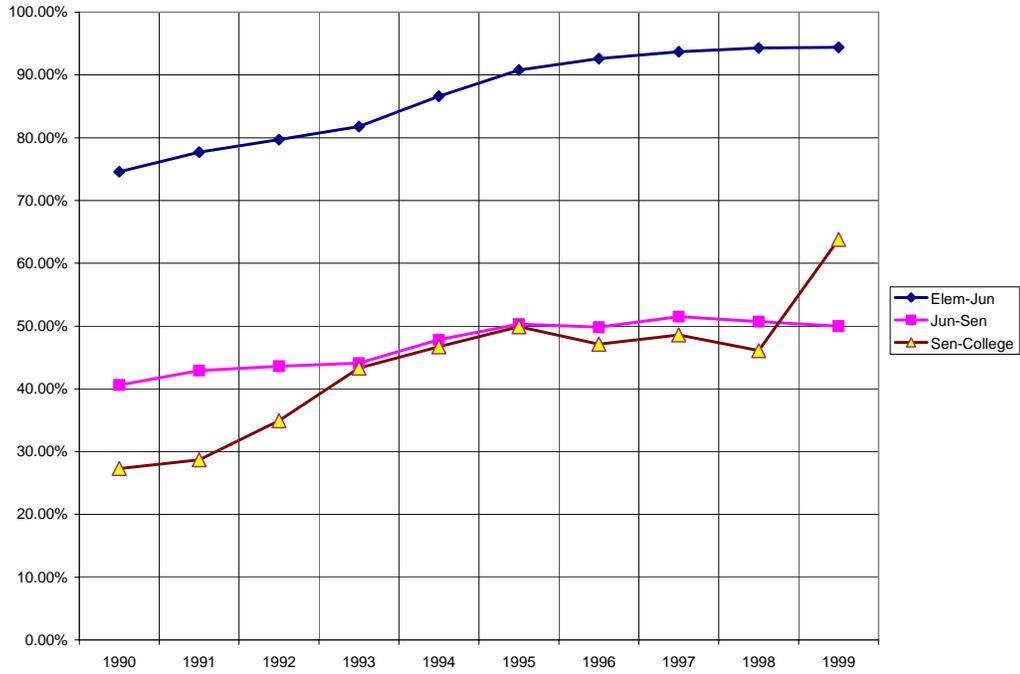


Figure A-1. China's School Admission Rates

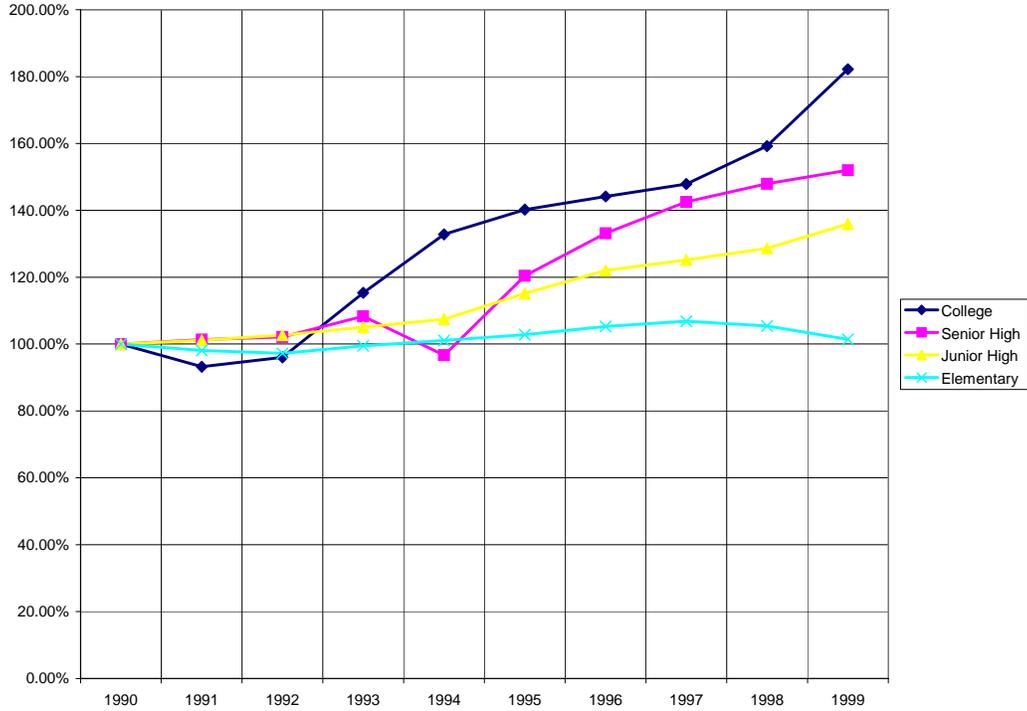


Figure A-2. The Enrollment Rates at Different Levels of Schools

### APPENDIX III: CHINA EDUCATION AND RESEARCH NETWORK (CERNET)

The China Education and Research Network (CERNET) [NRC, 2004A, 2004B AND 2004C] is the first nationwide education and research computer network in China. The CERNET project is funded by the Chinese government and directly managed by the Chinese Ministry of Education. It is constructed and operated by Tsinghua and other leading universities.

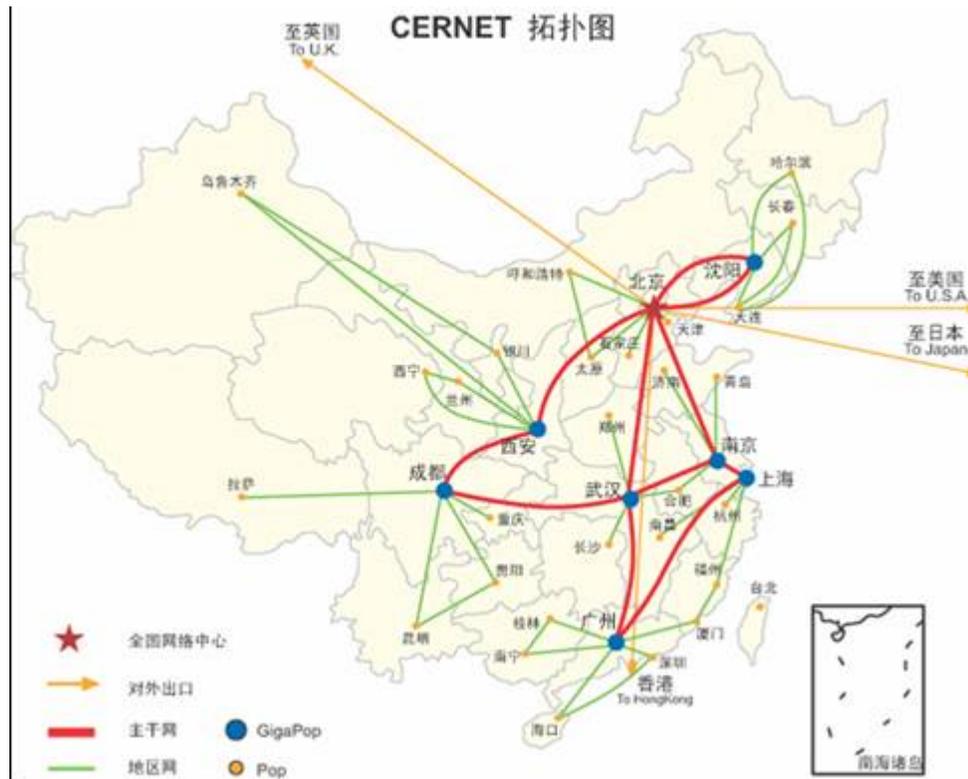


Figure A-3. The Network Configuration of CERNET

As shown in Figure A-3, CERNET uses a four-layer hierarchy: the nation-wide backbone, regional networks, provincial networks, and campus networks. CERNET National Center is located at Tsinghua University, which is responsible for operation and management of CERNET backbone nationwide. The ten regional network centers and the main nodes are distributed in Tsinghua University, Beijing University, Beijing University of Post and Telecommunication, Shanghai Jiaotong University, Xi'an Jiaotong University, Central China University of Science and Technology, South China Institute of Technology, China University of Electronic Science, Southeast University and Northeast University. These universities are responsible for operation, management, planning and construction of CERNET regional backbones.

CERNET evolved through three phases:

#### I. Startup Stage (1994--1995)

In November 1994, the State Planning Commission formally approved the feasibility study report of CERNET Pilot Project. In the first year, CERNET built up the national backbone connecting 8 major cities, implemented international accessibility, and

completed the CERNET National Center, eight regional centers and two major nodes. It essentially created a relatively complete network management and operation system and developed a spectrum of network resources and application systems. By the end of 1995 when the CERNET Pilot Project was accepted, CERNET connected 108 universities and colleges around China except Tibet, Hong Kong, Macao and Taiwan, with more than 30,000 login users.

## II. Growth (1996-1999)

Starting in 1996, CERNET migrated into a stage of consolidation, expansion and growth, in which three major projects were completed:

- The Study Project on Crucial Technologies for Computer Information Network and Its Application,
- CERNET Backbone Upgrade Project, and
- CERNET Regional Backbone and Key Subjects Information Service System Project.

## III. Further Evolution (2000~2004)

In this phase, CERNET was upgraded and expanded to an important infrastructure in China's information initiative. The State Planning Commission approved the "CERNET High-speed Backbone" Project in September 1999. By the end of 2000, the bandwidth of the CERNET backbone was upgraded to 2.5Gbps and the transmission rate of the regional networks reached 155Mbps. In 2003, the international gateways, connecting to the Internets in the United States, Canada, UK, Germany, Japan and Hong Kong, provided a total bandwidth of 800Mbps. More than 900 education and research institutions were connected to CERNET with a user population of 13 million.

By 2004 CERNET was an experimental platform for China to research the next generation of Internet applications. Relying on the established network facilities, CERNET set up a pilot IPv6 network. In 1998, CERNET joined IPv6-6BONE, an experimental IP-based network of next generation, and became one of its backbone members. CERNET is the first network in China that interconnects with Internet2, the next generation of Internet. In 2002, the ChinaGrid project, a CERNET-based grid network covering more than 100 universities in China, was launched. In 2004, CERNET2, the first IPv6 backbone was put into operation (NRC, 2004b; Li et al 2003).

## APPENDIX IV: LIST OF ABBREVIATIONS

Terms	Meaning
ADL	Advanced Distributed Learning
ADSL	Asynchronous Digital Subscriber Line
API	Application Programming Interface
ARIADNE	Alliance of Remote Instructional Authoring and Distribution Networks for Europe
CAPS	Courseware Authoring and Production System
CERNET	China Education and Research NETWORK
CMI	Computing Managed Instruction
CN	China
CNNIC	China NIC
CQM	Coordination and Quality Management
DTD	Document Type Definition

DWDM	Dense Wavelength Division Multiplexing (fiber optic communications)
EJB	Enterprise Java Bean(s)
EU	European Union
EVITech	Espoo-Vantaa Institute of Technology
FEIC	Fujian Economic Information Center
Gbps	Gigabits Per Second
GDP	Gross Domestic Product
HTML	Hypertext Markup Language
IE	Internet Explorer
IEEE	Institution of Electrical and Electronic Engineers
IEEE LTSC	IEEE Learning Technology Standards Committee
IMS	Instructional Management System
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
JDBC	Java Data Base Connectivity
JMS	Java Messaging Services (Java API)
JSP	Java Server Pages
KWAFU	KWAFU is a name for an ancient Chinese man in a Chinese myth who chased the sun, and is used as the name for the Tsinghua components of NCEC
LM	learning material
LMS	Learner Management System
LO	learning objects
LOM	Learning Object Metadata
MII	Ministry of Information Industry
NBCE	Network-Based Collaboration Environment
NBLE	Network-Based Learning Environment
NCEC	Network-Training Collaboration in Europe and China
NRC	Network Research Center
NSDRC	New Service Development and Research Center
OMT	Object Model Template
PEMC	Project Executive Management Committee
RMB	Ren Min Bi (currency of People's Republic of China)
RMI	Remote Method Invocation
RTD	Research and Technological Development
RTVU	Radio and TV University
SCORM	Sharable Courseware Object Reference Model
SDH	Synchronous Digital Hierarchy
UML	Unified Modeling Language (Object Management Group, OMG)
UOCAS	User-Oriented Courseware Access System
XML	eXtensible Markup Language
XSL	eXtensive Stylesheet Language
XSP	eXtensible Server Pages

## ABOUT THE AUTHORS

**John Gordon** is a Chartered Engineer, Chartered Mathematician and an experienced European learning technologist. He holds BSc, BA and MPhil degrees. He has been active in many research projects and involved in major EU funded projects in the applications of e-learning technologies. A consultant internationally for many years, he advised governments and major companies in the applications of technologies for learning. His commercial experience includes directorships of several IT companies. His current projects include the SQA qualifications in e-Learning, two research projects with a network of EU companies, and an MSc in IT. John led the Microelectronics Education Development Centre (MEDC), University of Paisley, the main support

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