Web-Based Education Techniques: Workflow, Collaboration, and Quality of Service

Michael R. Lyu
Computer Science & Engineering Department
Chinese University of Hong Kong
Hong Kong SAR, China
Tel: +852 2609 8429, Fax: +852 2603 5024, E-mail: lyu@cse.cuhk.edu.hk

Yiu-Sang Moon
Computer Science & Engineering Department
Chinese University of Hong Kong
Hong Kong SAR, China
Tel: +852 2609 8415, Fax: +852 2603 5024, E-mail: ysmoon@cse.cuhk.edu.hk

Wing-Kay Kan
Computer Science & Engineering Department
Chinese University of Hong Kong
Hong Kong SAR, China
Tel: +852 2609 8437, Fax: +852 2603 5024, E-mail: wkkan@cse.cuhk.edu.hk

Mladen A. Vouk
Department of Computer Science
North Carolina State University
Raleigh, North Carolina, U.S.A
Tel: +1 919 515 7886, Fax: +1 919 515 7382, E-mail: vouk@adm.csc.ncsu.edu

Abstract: In this paper we describe and evaluate a set of Web-based and workflow-sensitive educational techniques that can increase the effectiveness of teaching, collaboration, and resource sharing. These techniques allow educators to facilitate the goal of developing high quality teaching and learning, using the fast growing Internet technologies. We construct a system that supports implementation of these techniques in a broad range of institutions of higher learning. The system operates in the context of an efficient state-of-the-art, network-based engine that supports advanced virtual laboratory concepts, and collaborative content capture, development and delivery mechanisms. This support system, called "Multimedia Web-Presentation System", is easy-to-use, adaptable to user workflow, profiles, and quality of service needs, and is affordable for wide distribution and adoption. We also discuss Web-based education issues and describe how our system can be used to address these issues.

1. Introduction

Advances in computer and communications technology have opened an unprecedented opportunity for satisfying many educational needs and bringing a wide variety of educational applications closer to a broad base of potential users. It is our experience that today end-users of educational and training services should, and do, expect not only provision of high quality educational and training material, but also smooth integration of this material and training with advanced computational and networking frameworks, and with the day-to-day operational environments and workflow within which they operate (e.g., industrial, government, or academic settings). Education workflow is often as complex, and structured with intricate dependencies, as most complex scientific research or manufacturing workflow.

There have been many impressive achievements in the application of computer technology to education, and most informed observers would agree that there is much more to come. However, to date, most of these achievements can be classified as "point solutions" targeted at solving a particular problem within the academic arena; e.g., a set of courseware modules for teaching engineering statistics, or a computer game designed to sharpen the spelling skills of a first grader. There are many reasons for that: some are technological, but some are related to system requirements and development issues. In the not-too-distant past, insertion of computer-related innovations into the educational process was a major undertaking, both technically and economically, usually requiring the setup and maintenance of a particular hardware and software environment specific to the individual educational tool or program.

The advent of the World Wide Web was a breakthrough in terms of defining a standard, albeit a somewhat primitive one, for information content independent of the underlying hardware and software delivery system. This simple decoupling of information content and delivery system has been largely responsible for the explosion of activity that we have witnessed on the Internet.

The next step, seamless and wide-spread integration of new computer and networking technology into everyday educational workflow and paradigms - similar to the "*appliance*-like" adoption of whiteboards, overhead projectors, and video technology - is still to come. Most of available web-based education (WBE) systems are not yet "appliances." Most require too much effort on the part of the users (students, instructors) in both technological and content areas, and they still represent a disproportional distraction from the regular educational workflow of typical instructors or students, to be adopted as "appliances" in any but its most primitive form (e.g., plain Web pages). We believe that this will change only in systems that

a) Provide appropriate and high quality content;
b) Support appropriate user-profiles, functions, and user-oriented framework; and
a) Dynamically adapt to user learning and other higher-level quality of service needs.

Very few network-based education (NBE) systems were ever developed based on actual user-level quality of service considerations, and to the best of our knowledge, only one continuously assesses its own performance and offers that information to its users dynamically on a routine basis [Dixit et al 1996].

2. Education Workflow and Users

We take a system view of education using the "workflow" concept [Bitzer 1973, Singh 1994, Rindos et al 1995]. This concept recognizes the educational process as a system which involves interactions among a variety of individuals including (but not necessarily limited to) teachers, researchers, learners, advisors, and administrators; through a series of workflow primarily involving the access, creation, teaching, or manipulation of the subject matter. These activities become particularly intense and difficult to manage and synchronize when one wishes to integrate them with research workflow that arises in rapidly changing fields, such as multimedia, advanced networking, and parallel computing. Understanding the educational workflow is the key to effective application of technology to the process. Only when advanced computer technology is correctly mapped to the educational process through the workflow model, can its fundamental benefits begin to approach full realization. The key to the understanding of the workflow is a clear understanding of the entities that create and sustain it.

The most important NBE system entity, and the principal quality driver and constraining influence is, of course, the user. NBE users can be classified into a number of categories. Four non-exclusive general categories are of prime importance: students, instructors, authors, and system. System developers are responsible for development and maintenance of the system software and resources, authoring tools, courseware tools, and so on. Authors are courseware developers. It is essential that authors are both pedagogical and content experts, but they may not be system experts. Thus, authoring tools and interfaces provided by the system developers must be easy-to-learn and easy-to-use so that the authors can concentrate fully on the lesson development. Instructors deliver the course material. They sample and combine existing lessons, customize, update and develop courses and projects. System supports for tutoring, student-instructor interaction, student evaluation, etc., are essential instructor functions. Students are the most important users of the system. They require appropriately reliable and timely lesson delivery, easy-to-use interfaces, collaborative supports in local and remote joint projects, instructor's help, and so on. Since the "class" of the future is likely to include students and instructors who are widely separated geographically, who may not able to "attend" lectures on a preset schedule, and who come with very different backgrounds, the tasks for system support and instruction should scale the barriers of space and time as well as of student diversity.

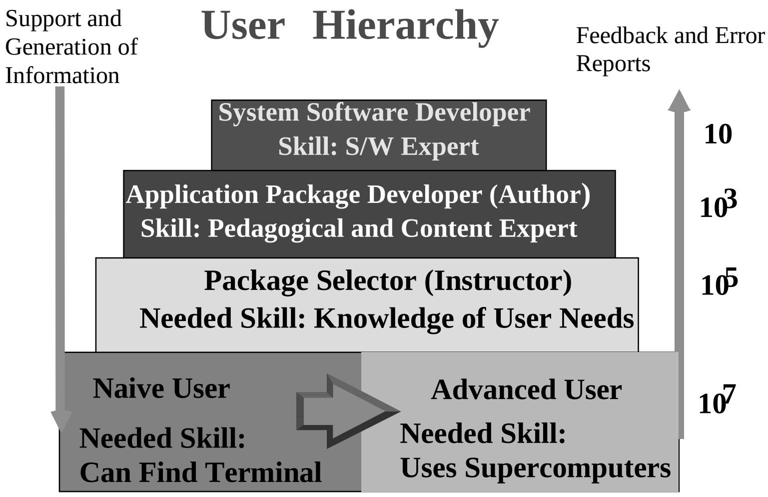


Figure 1: General categories of user of an NBE system

An illustration of the relationship among the four principal general user categories is shown in Figure 1. In our opinion, a successful large-scale wide-area NBE system should:

a) Support a very large number of students that range from very naive to very sophisticated.
b) Support construction and delivery of curricula to these students. To do that, the system will need to provide support and tools for thousands of instructors, teachers, professors, and parents that serve the students.
c) Support generation of adequate content diversity, quality and range. This may require support for many hundreds of authors.
d) Be maintainable with a relatively small number of systems personnel.

Obviously, the system architecture and solutions have to be scalable. Furthermore, clear and direct lines of communication should be provided for user-generated feedback and error reporting. The system, and its personnel, must provide rapid response to any problems in order to maintain adequate system reliability and quality of service.

Education workflow is expected to coexist, cooperate and meld with other user workflow (e.g., business, scientific or legislative workflow), therefore they must support compatible interfaces and constraints. We call this "horizontal" integration of the workflow at the level of end-users. For example, many students from industry that work during the day may prefer to incorporate the majority of their continuing education into their daily or weekly routine at times that suite them, e.g., evenings or weekends, because they cannot match their work-place processes with the traditional school, college or university teaching workflow. However, this particular challenge to "traditional" education workflow cannot be met without extensive technological and pedagogical support which allows a) decomposition of the synchronous teaching/learning cycle into a primarily asynchronous component (with minor synchronous interactions), and b) at the same time preserves and maximizes the quality of learning and the knowledge transfer rate that is normally associated with the "classical" synchronous teacher-student interaction. Other functionalities are needed in the case of other types of horizontal integration. From the perspective of the current proposal, the most important component is the horizontal integration of educational and research workflow. This frequently requires very strong support for collaborative activities. Interactions and negotiations also have to take place between the end-user layer of a NBE environment and the underlying infrastructure (platforms, software, computer hardware, interconnecting networks) in order to provide the throughput, keystroke delays, jitter, and other services, that an NBE application or user expects. We call this "vertical" integration of education workflow with event, control and data flows that occur at infrastructure layers. The network- and platform-related flows and service capabilities of the information infrastructure (e.g., power of the user platform, network capacity, supercomputing facilities) have to be appropriately matched and interfaced with the needs of the user’s educational and training workflow.

Application of the workflow technology to a specific course requires information about the syllabus, participants (both faculty and students), schedules, and instructional facilities and technology, and development of the corresponding operational profile for the NBE system. Operational profile is the set of relative frequencies which tells us how often is a particular function or capability requested in practice [Lyu 1996]. Specifically, given a syllabus, schedule, and the student profiles, one would first categorize the students by qualifications and learning styles, then one would produce a mapping between the syllabus topics and the student learning models. This would allow mapping of the needed content teaching approaches to content topics. This mapping may include the placement of feedback points, an estimate of the process feedback rates, location of testing points, and material reinforcement information. The final step would be to map these needs to NBE system functionalities, based on instructor/author qualifications and preferences, available resources, etc., to obtain an operational profile that needs to be supported during the course. The mappings and the operational profile allow us to recognize teaching alternatives and introduce adaptive or fault-tolerant teaching into the educational model.

We can also integrate the research results into academia courses. Examples of “fast changing areas” of research and education are multimedia, networking, and high-performance computing. The research in such areas is very intense and the “state-of-the-art” is changing very rapidly. Academic courses related to these areas are liable to be “behind times” unless they are frequently “refreshed” with research results. In general, two sets of issues arise:

(1) How to minimize the impact and cost of geographical dispersion of researchers, course authors, course instructors, students, and advanced instructional and laboratory facilities, but maximize knowledge transfer for the class or students under consideration; and
(2) How to appropriately but rapidly author, manage, re-use, and disseminate research enriched courseware (e.g., standardized lecture objects, lessons).

The solution is the one that also includes workflow- and user-sensitive collaboration. Collaboration and team work have been the key to advances in modern society. A correctly constructed paradigm and system will actively support experts who integrate contemporary research results into courseware, and will enhance the communication and learning among students. At the same time, such an approach will speed-up and reduce the cost of the process. Based on these concepts, we describe a system we have developed to facilitate the collaboration needs in quality education.

3. Multimedia Web-Presentation System

Multimedia Web Presentation System (MWPS) supports construction, editing, and management of Web-based presentations, and synchronous and asynchronous capture and delivery of classes and lessons.Using existing technology, such as Web browsers, HTTP servers, HTML documents, CGI programs, Javascript, Java Applets, and RealAudio™, MWPS implements methods for automatically generating and serving Web-based multimedia presentations based on live versions of the same presentations. The presentations consist of HTML documents with streaming synchronized audio and video. The streaming can be of the low-bandwidth variety or they can be of the Internet 2 variety (e.g., MPEG-2 based).

MWPS contains an on-line editor that allows instructors to prepare slides for delivery. However, for development of Web pages and animations, we encourage use of commercial HTML and Web-site editors and environments, such as HomePage, PageMill, FrontPage and similar, or tools such as PowerPoint. MWPS can work with outputs from all these tools.

In operation, WLS captures audio/video and timing data during live (synchronous) presentations and automatically broadcasts and creates a web-deliverable version of the presentation. All of the details of the underlying system are hidden from the users, both instructors and students. WLS allows users to view a presentation using a standard Web browser, such as Netscape, and listen to or view the accompanying streams via a RealNetworks audio/video player [RealNetworks 1998]. The system also has the ability to deliver live presentations with student interaction.

This system greatly facilitates delivery of the required workflow, collaboration, and quality of service for our teaching and learning needs. The screen shots of MWPS are shown in Figure 2 through Figure 7. Figure 2 shows the front page of MWPS. Figure 3 depicts the sign-on page for the presenter who is ready to make a presentation. Figure 4 describes the presentation control panel for the presenter to prepare a presentation. Figure 5 indicates the control buttons in a presentation screen. Figure 6 captures a live presentation (can be in synchronous mode or in play-back mode), including video, audio, and view graphs. Figure 7 illustrates a whiteboard facility available to the presenter for drawing and highlighting.

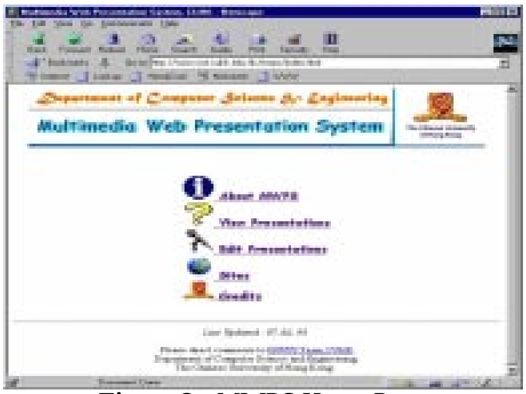


Figure 2: MWPS Home Page

Figure 3: Presenter Sign-On Page

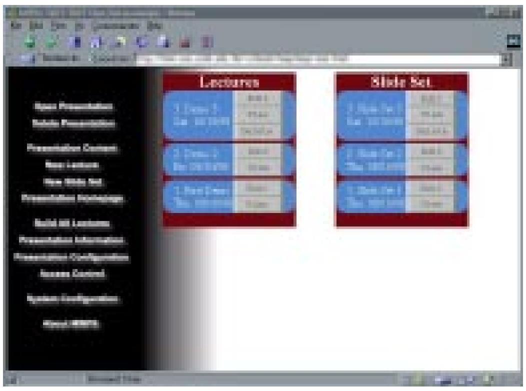


Figure 4: Presentation Control Panel

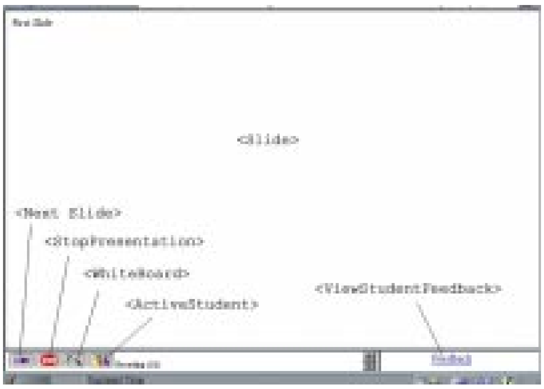
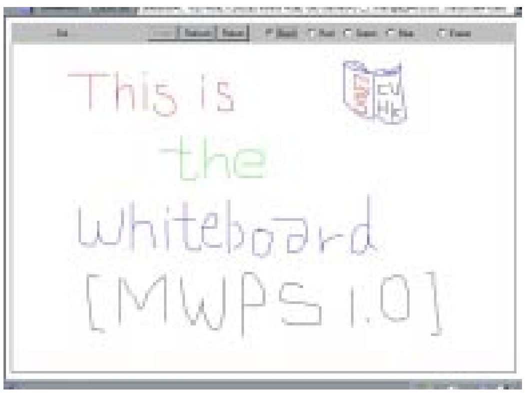


Figure 5: Presentation Screen



4. Web-Based Education Techniques

The primary goal of our effort is to enable rapid introduction of research results into academic courses in the so-called "fast moving areas". These courses will be broadcast over the Internet, and will be available in both synchronous and asynchronous modes. These courses plan include the latest relevant research results, and the courses will use the Virtual Laboratory technology to distance-share state-of-the-art networking and multimedia resources.

Collaboration, combined with workflow, user-orientation and modern networking and computing technology, is the key to successful cost-effective integration of research into academic courses. Potential collaborative activities include [Vouk et al 1999]:

?? Collaboration among authors, joint courseware development. Experts can contribute to those parts of a course that are in their domain of expertise. The collaborative effort can minimize the courseware production provided courseware organization and lesson formats are standardized to facilitate integration and re-use of the material.

?? Sharing of special facilities and simulations. Expensive state-of-the-art facilities of one institution can be made accessible to another institution via a virtual laboratory. A student can remotely access the targeted facilities through Internet and control all relevant parameters when conducting a hands-on activity. This can greatly increase the opportunities for students who might have limited facilities in their local institutions.

?? Collaboration among, and with, learners can significantly enhance the learning experiences. One way to encourage such collaboration is to design team projects for the courses offered. Students who are physically apart should be allowed to perform joint work. This requires groupware that facilitates file sharing, collaboration, discussion among distant students, and so on.

MWPS can facilitate a cooperative educational environment which provides quality teaching and learning components, including virtual laboratory, groupware, course organization and storage, and quality of service.

(1) **Virtual Laboratory** (VL). This idea dates back to the early days of NBE. Examples of "learning-by-doing" are computer-based laboratories that many learning environments provide. A classical example is the full-interaction “distillation experiment” implemented in PLATO. Web-resident examples abound as well. From the “Web-Telescope (Mt. Palomar.)”, to collaborative environments such as IRI [Maly et al 1997]and TANGO (http://trurl.npac.sy.edu/tango/), to several remote electron-microscope labs, and similar Internet 2 applications. The VL concept is fully explosed since a major focus of our effort was to stimulate hands-on and constructivist learning. Rather than merely presenting abstract, decontextualized information to students, our MWPS system can facilitate the acquisition of scientific principles by enabling students to design and troubleshoot complex devices and networks of devices. Recent advances in visualization technology enable us to create expansive and intricate synthetic environments that are ideal for this learning-by-doing paradigm. Equipment will be accessed through virtual laboratories to eliminate the geographical constraints.

(2) **Groupware**. Students taking classes at a distance need collaboration. PLATO and NovaNET [NovaNET 1998] were the first multimedia learning environments that supported extensive interaction among students as well as communication between the tutors and the students through a facility that lets one or more of the collaborators "watch" and interact with the screen of another collaborator. There is currently a host of commercial tools that provide similar or more extensive facilities. These range from teleconferencing, to whiteboard sharing to “chat-rooms.” Examples are full versions of Netscape and Microsoft WWW browsers, the MBONE toolset [McCanne and

Jacobson 1995], the First Virtual toolset, numerous "video-over-IP" ventures, Microsoft's Netmeeting, and so on. Groupware for collaborative project development should also consider synchronous and asynchronous group document control and maintenance. We have implemented the MWPS system for groupware applications that integrate shared document management and teleconferencing to support the collaborative activities among learners.

(3) **Courseware Organization and Storage**. The organization of the course material can be crucial to the effectiveness of the instruction. Proper organization should consider issues such as the integration of course content developed by multiple instructors (re-use), proper break of presentation flow to allow insertion of activities on-the-fly, convenient random accesses, etc. MWPS materials are organized into classes. Each class owns sets of slides. A slide can be either a local HTML page, or a URL. Lessons can be constructed out of any of the slides that belong to the course, or if URLs are used, to anyone, in any order and as many times as needed. Since audio, video and text/graphic data are typically stored on different servers, the database has to be distributed. Our course organization is more oriented towards support of learning objects and their meta representations. It can be represented by a hierarchical graph, with topics and subtopics being represented by nodes and directed links associating subtopics to topics. For a given node (topic), summary and keywords are attached as attributes to the node to facilitate search and topic integration. Examples and case-studies are linked as subtopics to a topic. Text, viewgraphs, sounds, graphics, animations, and/or videos are independently associated with a node to facilitate individualized storage, playback and adaptation that conforms with end-users media and networking preferences and/or constraints. Information about synchronization and about conversion options between high-bandwidth formats and low-bandwidth formats is also associated with the node. A search engine will search for specific topics and keywords.

(4) **Quality of Service** (QoS). Traditional (network-related) QoS is defined by a number of measures. These include keystroke delays, probability of loss of data, jitter, and throughput [Chen et al 1997]. In the context of end-user oriented workflow, we broaden the classical definition of QoS to also include measurable end-user quality characteristics such as system reliability and availability, performance, algorithmic scalability, effectiveness, quality of lessons, quality of user-system interactions, semantic interoperability, and so on. For example, EDSS and NovaNET related studies show that synchronous end-to-end interaction (round-trip) delays that consistently exceed about 250 ms are often unacceptable from the user point of view when the interaction is conducted in the keystroke-by-keystroke mode [Bitzer 1973, Dix 1998]. Similarly, NovaNET system measurements indicate that, once a user starts one hour of work (e.g., a lesson), to maintain reasonable user satisfaction, the probability of getting through that hour without any problems should be above 0.95, while probabilities below 0.86 are totally unacceptable [Dixit 1998, Avner 1993].

To date very few research projects address the QoS issue in Web-based education. To assure adequate reliability and availability of a lecture session, we need to consider fault tolerance [Lyu 1995] for our system servers (which are the source of the lectures) as well as the network (which transmits the lecture material). Fully operational, our system should be able to support a large number of simultaneous users. Single-system server architecture incurs not only the problem of single-point failure but also potential overloading. Currently MWPS operates separate servers for different MWPS functionalities: a WWW server, a low-bandwidth streaming media server, and a high-bandwidth streaming media server. However, there is no stand-by or other type of dynamic fault-tolerance, nor run-time overload protection.

5. Summary

The option of obtaining education over networks is quickly becoming a reality for all those that have access to Internet and World Wide Web. However, at present network-based education over WWW, or Web-based education, as well as any form of distance education over the Internet in general, faces a number of problems. These problems range from potentially inadequate end-user quality of service, to inadequate materials, to lack of learning paradigms and student assessment and feedback mechanisms. In this paper we discuss some major issues that face web-based education WBE, and NBE in general, including the required technological and quality of service support. In discussing the issues, we have used examples from a WBE system called MWPS, and demonstrated its capability in providing educational workflow and course material over the Web.

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