Information Technology Enhanced Learning in Distance and Conventional Education

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Abstract— **The rapid growth of the Internet and the media-rich extensions of the World Wide Web allow new developments in the way instructors transfer knowledge to their students. There is no doubt that nothing will replace synchronous learning through face to face interaction but it is sometimes not feasible for students to attend conventional classes due to distance or time constraints. This paper presents a model for using information technology to enhance the learning experience for conventional on-campus students, as well as for those students whose circumstances require that they be asynchronous in time or space. The approach described emphasizes a solution which allows students to attend the class in real time via the Internet, or to access asynchronously digitally stored video material with hyperlinks to online training resources at any time. The proposed solution permits interaction in real-time and asynchronously among students and between students and instructor, which is a key for effective learning. In addition, the Instructor maintains a significant level of spontaneity in using multimedia material prepared in advance or using conventional chalkboard or hand written materials via traditional overhead projection. The paper describes the technical issues involved and the chosen solutions to provide enhanced live and archived classes. This paper provides some comments on the evaluation of the learning experience using this method of delivery for on-campus and distance education students. Finally we share our vision on future trends to improve the proposed learning environment and the need for an optimal balance between expositive teaching and active learning for both synchronous and asynchronous activities.**

***Index Terms*—ALN, asynchronous learning networks, distance education, on-line education.**

I. INTRODUCTION

THE conventional instructional style of a teacher with chalk in front of a classroom is still the main stream in education. However, in recent years, various modes of distance education have caught the interest of educators [1]–[3].

It is our view that the traditional model of an instructor and students present in the same time and space, provides the best quality of education because of the almost unbounded modes of communication and interactivity made possible by physical presence. However changing lifestyles and more demanding schedules are forcing more and more students to reap the benefits of academic instruction remotely and the attendant demand for distance education is growing exponentially. Additionally, the availability of increasingly powerful communication and information technologies have opened the way for enhancing traditional teaching and learning in both distance and conventional education using synchronous and asynchronous tools. The notion of asynchronous learning [4] has been around for some time in such embodiments as correspondence schools, videotapes, audiotapes and written material sent by postal or courier services, and more recently via multimedia WWW pages. In this mode students can have access to instructional material at any time and from any convenient location. Asynchronous learning networks (ALN's) provide in addition a network of people who can interact with each other using electronic connectivity tools to simulate the interactivity of physical presence. Despite the clear advantages of the asynchronous learning tools for both distant and local education, the extensive preparation and planning required for the delivery of class material via multimedia asynchronous methods has been a major challenge.

In this paper we describe the experiences accumulated in the Department of Electrical and Computer Engineering [5] at the University of Florida in developing asynchronous learning materials using traditional delivery methods and by integrating leading edge technologies which combine conventional synchronous and the more recent asynchronous learning networks. The idea is to generate usable low latency, low bit rate video and audio stream of the instructor as he or she lectures by using prepared slides or other material, or spontaneously writes on the chalkboard or writing tablet. The key is for the audio quality to be good ("telephone quality") and the video to be good enough for written material to be legible. The video and audio streams are broadcast via an IP network to students synchronized in time but asynchronous in space. Students can then interact with the instructor in real-time via voice-over-the-net systems or via electronic conference software such as IRC or similar clients. In Section III we report on the performance from the on-campus and off-campus student perspectives as well as from the instructor's point of view with a variety of compression schemes, transmission rates, and various auxiliary information sources.

The tremendous advantage of the proposed synchronous scheme for joining a class in real-time from a remote location is that the end user does not need to have expensive equipment for participating in the classroom, as is the case of circuit switched videoconferencing. A PC with a 28.8-kbps modem

Manuscript received October 7, 1996; revised August 5, 1999. This work was supported by a grant from the Alfred Sloan Foundation as well and the National Science Foundation Southeastern University and College Coalition for Engineering Education (SUCCEED).

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Publisher Item Identifier S 0018-9359(99)09009-3.

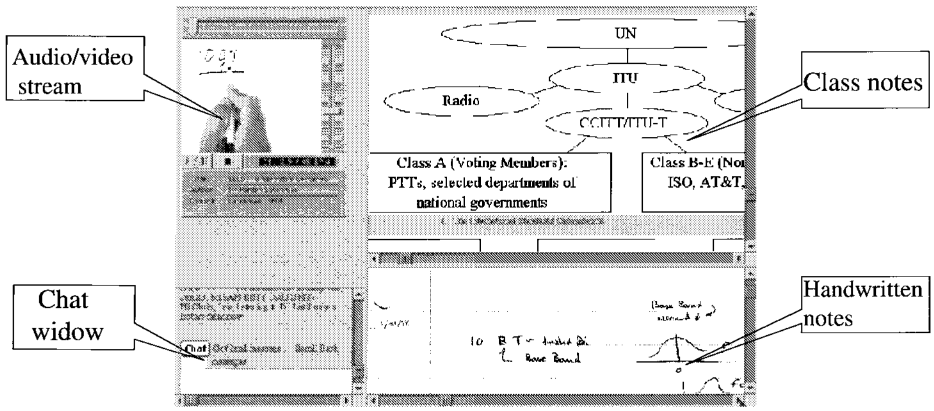

Fig. 1. Web-based asynchronous lectures.

dialup link and a Web browser brings the virtual classroom to the users at home or work. If the student is on campus with access to a local area network (LAN) it is possible to get a higher bandwidth with even better performance. In addition the system allows many students from various locations to join the synchronous lecture at any time.

At the same time that the lecture is being transmitted digitally, the audio and video streams are archived so that students can access the material from anywhere and at any time, and essentially see the material as it was broadcast live. In this case live interaction is replaced by asynchronous interactions via mailing lists, bulletin boards, and WWW pages. In addition, we show that the asynchronous experience can be greatly enhanced by an incremental investment of time in synchronizing the lecture notes and other materials such as scanned handwritten documents of the instructor or students notes taken during the class, or even PowerPoint, WWW slides, interactive java applets or simulations. The effect of the synchronization is that the browser automatically advances to the appropriate lecture material in another display window as it is being discussed by the lecturer.

II. Technical Functionality

A. Overview

A number of issues are involved in the transition from synchronous to asynchronous and hybrid learning networks. The fundamental idea behind the efforts at the University of Florida is to allow the enrolled student to reap the benefits of online courses that combine the best aspects of Internet services, multimedia, and effective teaching. In order to realize these objectives, the system being developed should be capable of providing a low-cost content-rich resource which encourages the students to explore new avenues of learning.

Fig. 1 shows the various objects used to convey information and facilitate interaction among the students and with the instructor. The system is designed for use in real-time lectures as well as for asynchronous delivery. The key components are an audio-video window, textual/graphic windows and links to chat rooms and mailing lists. In what follows we describe the specifications for each of these components.

A basic requirement is to generate a low latency low bit rate live video and audio stream of the instructor lecturing in the classroom. The audio quality should be at least “toll” quality and the video quality should be good enough for the written material on the board or the slides from overhead projector to be easily read by remote students.

The target data rate for audio and video is about 20 kbps. This is a stringent requirement considering the fact that this bandwidth will support useful audio and video signals. However the target data rate of 20 kbps on a typical 28.8–33.6 kbps link will leave the student with enough bandwidth for other communications (such as lecture notes, WWW pages and feedback) in addition to the audio/video streams. Of the two streams the audio will have to be at least 8 kbps for the required level of quality with conventional codecs and thus the video occupies only about 12 kbps. Since the audio and video streams are independently generated, there should be a tight level of synchronization between the two. If the latency (at source while compressing) is different for the two streams, the audio and video will eventually fall out of sync during the course of a lecture. While the information content of a talking head is minimal, the fact that spontaneously written material is also transmitted in the video window justifies the inclusion of the video facility. An alternative for asynchronous consumption is to provide a choice of combined audio/video streams at various rates as well as an audio only source so that the user can select the stream most appropriate for his network connection.

For real-time lectures the generated audio and video streams from the classroom are to be broadcast over the Internet to students synchronous in time but asynchronous in space. Since the IP network is the delivery medium, the content delivered suffers from the inherent disadvantages of the network, namely, variable and unpredictable end to end latencies and the lack of any guaranteed quality of service. To overcome this inadequacy some mechanism to maintain the live or real-time quality of the streams at all times should be employed. A primary objective of the audio/video stream is to provide the lecturer with some degree of spontaneity in lecturing style via a high quality audio and a reasonable quality video usable by the remote student. To compensate for the very small video image of the materials written in real-time on

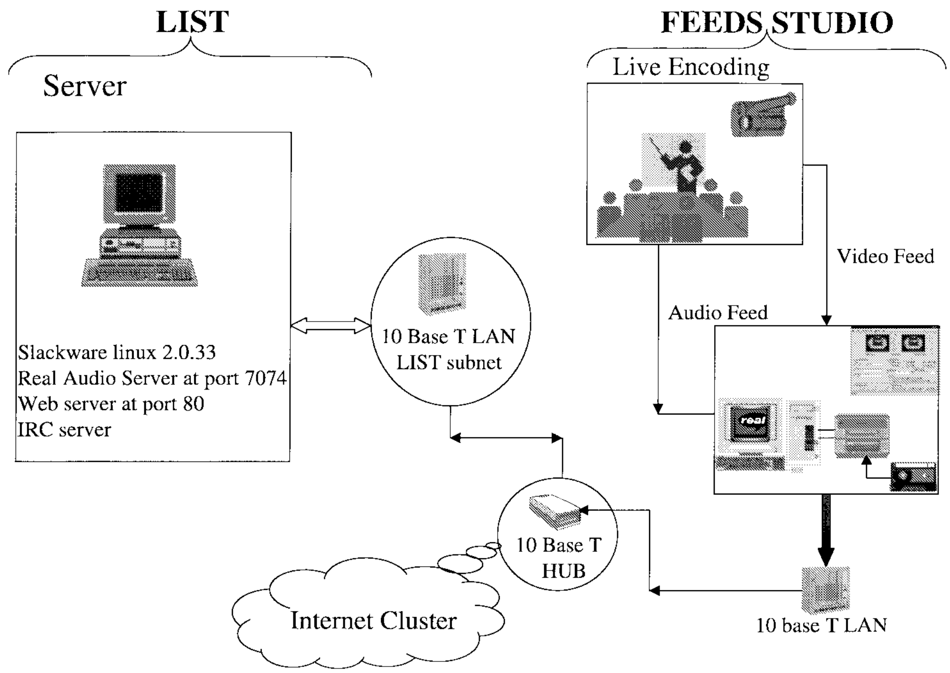

Fig. 2. Audio/video delivery.

the board or on overheads, an auxiliary web camera may also be used to periodically capture the written materials as a WWW image and transmit this information to the first data window. In archived lectures data window #1 can be used to display individual high-quality slides synchronized with the video window. Data window #2 is provided to allow flexibility in displaying other relevant materials such as interactive simulations.

An online WWW-based chat window is also included as shown in Fig. 1. This facility allows students at remote locations to interact with the professor during live classes, for example by submitting questions or images or even audio/video clips which can then be displayed or played to the class and an appropriate response given. Moreover, when a student is using the asynchronous mode of access, the chat facility can be used to submit questions or comments to the entire class. The contributions are archived so that the thread of the discussion can be followed at a later time.

B. System Architecture and Requirements

As discussed earlier the most important aspect of the virtual classroom is the effective delivery of audio and video content from the classroom. For this purpose the RealAudio and RealVideo system from Progressive Networks [6] is used. The live delivery of audio and video using the RealAudio/RealVideo tools roughly follows standard client server architecture. A schematic diagram of the system deployed at the University of Florida is depicted in Fig. 2.

The digitizing of video and audio is done in the classroom. The existing audiovisual equipment at the Florida Engineering Education Delivery System (FEEDS) studio provides audio and video signals for an in-class TV network and records the lecture on conventional VCR's. For real-time Internet delivery a video digitizer card and a sound card are installed on a 200-MHz-Pentium-machine running Windows 95. The digitizer is capable of real-time digitization at up to 30 video frames per second. The sound card is an industry standard 16-bit card. The PC hosting the real audio encoding software and video digitizer is connected to a 100 BaseT LAN. At the beginning of each class the RealEncoder is used to make a connection to the RealServer located in another floor of the same building through the LAN. The audio and video is digitized and streamed in real-time at 20 kbps to the server over the LAN. The frame rate of the video, audio bandwidth, and the total bandwidth is selected in such a way as to maintain a high level of synchronization between the streams and low overall latency. Bandwidth and latency considerations are described in later sections. At the server these streams are delivered upon request from Web browsers, with the current installation supporting up to 60 simultaneous streams. The content delivery from the server to an end user client is as shown in Fig. 3.

The sequence of events after the live stream reaches the Real Server is as follows:

The Web browser points to a page with a link to the real audio meta file [7]. The user clicks on the meta file link and the web server sets the MIME type to *audio/x-pn-realaudio*. The Web browser looks at the MIME type and starts the real player as a helper application. The real player reads the URL from the metafile and requests the real media file from the Real Server. In the present configuration the same machine hosts the Real Server as well as the WWW servers. However, as the load increases, it is anticipated that several independent servers will be needed. The real audio server begins streaming the requested audio/video files to the real player using the UDP streaming protocol. The live lecture

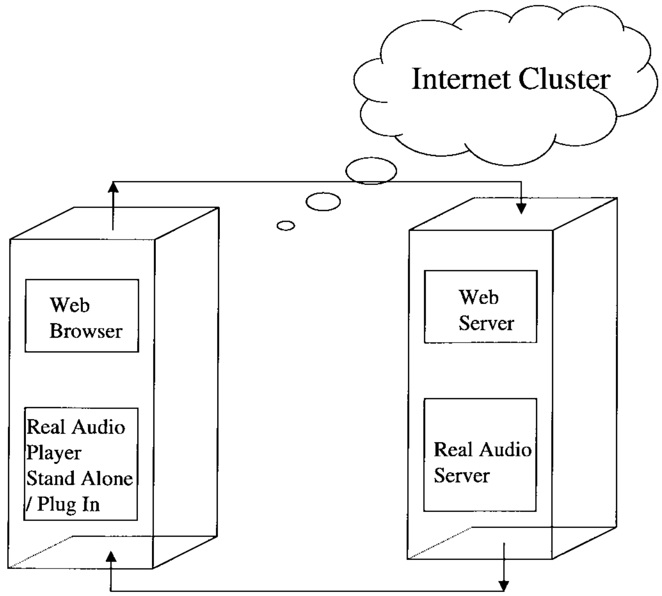

Fig. 3. Content streaming.

stream is also simultaneously archived in the server so that the students can access the lectures asynchronously at a later time.

For the archived lectures, the abundance of other class material also adds considerable value to the instructional content which can selectively be displayed in conjunction with the audio and video streams. The archived lectures are time tagged with the course notes so that while watching the lectures asynchronously, a synchronized multimedia presentation is possible. As the lecture proceeds the Web browser at the remote location automatically brings up the relevant course materials and slides in different frames.

Real-time interaction or feedback from the remote students is achieved via electronic conferencing software such as Web-based Bulletin Board System (BBS) software. In this testbed the instructor as well as the students log on to the same chat room. A provision to list all participants in the chat session is also desirable to mimic the "virtual presence" in the chat room.

In the case of archived lectures the BBS interaction is complimented by asynchronous interaction via mailing lists and WWW pages. All these resources are accessible by a Web browser from the main course page. Feedback received indicates that the asynchronous experience is greatly enhanced by synchronizing the lecture notes—scanned hand written instructor's notes or notes taken by a student during the class—to the video.

C. Bandwidth and Compression Schemes

Most of the remote students have a network connection from an ISP provider with a 28.8 kbps dialup link. In the testbed a bandwidth of 8 kbps is used for voice and thus the ceiling of 20 kbps limits the video bandwidth to 12 kbps.

Various compression techniques were tested to find the best tradeoff between bandwidth and quality of the video. Fractal compression is found to be very impressive above 56 kbps and higher. However, for live applications, fractal compression caused unacceptably high latency. An *optimal frame rate* scheme is presently being used for live lectures. In this scheme during a very active session characterized by fast moving images the frame rate increases and then decreases again during relatively inactive periods. This method provides the best quality video in the very limited bandwidth scenario. Initially a frame size of 240 $\times$ 180 was used and then changed to 160 $\times$ 120 because the former frame size produced a higher latency on a 28.8 kbps link. The effect was not noticeable over 10/100 Mbps LAN's. The color format used was originally RGB24 but this was changed to YUV9 because of the encoding delay and greater end-to-end latency. [It is also possible to have multiple encoders producing different bandwidth streams so that the end user has an option of selecting the appropriate stream depending upon the network connection.] Over a 28.8-kbps dialup link there were no noticeable packet drops. The maximum latency observed over a dialup link was less than 10 s. When observed from a LAN the latency was of the order of a couple of seconds. The actual frame rate over a LAN varied from 1 to 5 frames per second (fps) and over a dialup link the average frame rate is about 1/2 fps.

Some experimental data of the video compression process is given below (Table I).

III. Evaluation of the UF Experience

At the University of Florida this hybrid asynchronous and synchronous learning method has been used in the delivery of the Computer Communications course EEL5718, which is taken by first-year graduates and graduating seniors. Students were asked to attend the course synchronously in time but asynchronously in space both on and off campus. In addition several students took the course entirely asynchronously and the results of the learning experience were satisfactory to most of the students. The on-campus students who watched the lectures in real time over the campus network, had a much

TABLE I
REQUIREMENTS FOR MOVIE COMPRESSION

Original Video	Conventional Digitization	Real Encoder
NTSC-VHS Video =>about 300 usable lines	15 min. Video at 15 fps, 320x240, 16 bits colors, no compression, Sound mono at 8 kHz =>**600MB** file	15 min. Video with audio Control of the output bit rate, audio and video controlled separately, File size : 28.8 kbps => 2 MB, 56kbps => 4 MB, LAN 250 kbps => 9MB,

better video quality due to large available bandwidth, while the off-campus students who followed the course over 28.8 kbps-modems had a less perfect video quality but the audio stream was estimated by the users to be better than "toll" quality. The learning process through the synchronized multimedia format was evaluated by all participants to be better than video tapes since notes and other auxiliary materials were displayed on the screen so more attention was paid to the lecturer.

The entire set of lectures (about 40) of this course is now available on the Internet [5] for virtually anyone around the world who wants to take the course. The streaming audio/video material for the course occupies about 400 Mb of storage so that the complete set of course materials including lecture notes, slides and assignments can be stored on a standard 600 MB CD. This CD could then be distributed to students taking the course and they would then have direct access to the streaming audio/video from the CD while using the Internet for accessing interactive facilities such as online chat, mailing lists, and other frequently updated class materials.

A. Advantages and Limitations

Compared to the traditional way of teaching, this new method, which reaches students who otherwise would not have taken these courses, provides learning opportunities to a much larger and diversified audience, thanks to the absence of time and physical constraints. Students in different countries can now, without leaving their families or their companies, attend courses virtually anywhere in the world. In addition the fact that the archived lectures are available on the Internet as soon as they are taught while a video may take several days to reach the student constitutes a considerable advantage over common courier/mail delivery of video tapes since delays are minimized or eliminated entirely.

In addition, archived lectures allow students who are attending the course on-campus to view entire lectures or parts thereof as many times as necessary. In this aspect this method complements and enhances the traditional teaching.

Another advantage of the Internet streaming video technology over videotapes is the protection against unlawful copying of the audio/video material. While there is no simple way to prevent videocassettes from being copied, the streaming technology prevents lectures from being downloaded. Furthermore by changing passwords every year we can make sure that the lectures are not being illegally accessed by unauthorized users over time.

A great deal of educational and cognitive research has shown that the most effective learning environment involves interactive collaborative, "learning-by-doing" models. Clearly the traditional classroom setting facilitates spontaneous interaction among students and between students and instructors. However social preferences and learned habits often suppress this collaborative, active learning in most classrooms and many in-class learning experiences are simply one-way lectures. It takes a great deal of effort on the part of instructor and students to generate a collaborative learning environment in the classroom, in which students work in groups on problem-solving and share findings—discoveries—and insight with each other. This "ideal" in-class model may well be described as a "synchronous learning network"—a "network" of people learning from each other—with the instructor serving the role of facilitator and coordinator rather than the source of a one-way flow of canned information.

Our efforts in developing the hybrid synchronous and asynchronous learning model seek to simultaneously enhance the learning experience of three (3) distinct groups, namely traditional on-campus students, students at a distance who join the class in real-time via the Internet and students who take the class completely asynchronously.

1) On-Campus Students: The first group is the in-class students who can make use of the online materials at anytime and from a location of choice to supplement and complement their in-class learning. The asynchronous interaction such as electronic conferencing, chat-rooms and mailing lists provides alternative, and often, more desirable forum for collaborative learning, since many students are more comfortable with contributing to a discussion on their own terms, with ample time for reflective responses, rather than to be put on the spot in the live classroom. It takes much skill and sensitivity on the part of an instructor to get a lively and informal in-class discussion going without causing embarrassment to some students. The asynchronous mechanisms such as mailing lists and electronic conferencing systems do help in this regard—though experience has also shown that the meaningful use of these facilities must be encouraged and even required initially, so that the real benefits of these interactions can be perceived as a means to overcome inhibitions of custom. An additional benefit for on-campus students is that they now have greater flexibility in scheduling, since they can take some classes entirely asynchronously or via a live on-line connection from a remote location. Moreover, when entire courses are available online, the options become almost infinite: self-paced course completion, access to prerequisite classes, which are not offered by traditional classes in a given semester, as well as the ability to take a class when the traditional in-class sections are full. The list of potential benefits of the availability of high-quality asynchronous classes for even on-campus students is clearly significant and these open new possibilities and modes of learning.

2) Off-Campus Students—Live Lectures: The facilities described in this paper allow remote students anywhere on the Internet to join and actively participate in live on-line classes.

These students would simply point their Web browsers to the URL for the live classroom lecture [5] to get a connection to the streaming video and audio with optional links to the chat-room and online class materials. In this mode the student can ask questions as the lecture is being given using the live chat window. The instructor either repeats the question to the class or can display the question on the class TV monitors which is then sent via the streaming video to all participants. The investment in hardware and software on the part of the online student is simply a standard multimedia PC with at least a 28.8-kbps Internet connection. A full duplex sound card (or alternatively a second half-duplex card) would allow voice interaction as well as or instead of the live chat window. It takes some coordination effort to manage these interactions, such as the need for requesting permission to speak (say via the chat window) and being acknowledged by the instructor, being given permission to "speak" including access to the feedback audio system. However our experience is that for small groups of remote students the system works quite well, depending on Internet latencies. Of course, for live Internet classes, it does help to have the lecture materials online or sent *a priori* to the students, as well as frequent references during the lecture to tags or locations in the class materials to facilitate coordination. Our experience is that while the video window attempts to send what the in-class students see, some material is less intelligible than others. In particular, it appears to be quite difficult to find an optimal set of contrasts and colors in the video capture and encoding process which deals uniformly well with computer screen projections and material written on the chalk board. The use of multiway application-sharing programs such as NetMeeting provides a partial answer to this problem but further work is required in this area. A final point worth mentioning is that there is an unavoidable delay of several seconds between the live in-class lecture and the streaming video/audio at the remote students location. However the delay is usually tolerable on noncongested Internet connections.

3) Off-Campus-Asynchronous Students: Complete asynchronous access to the "virtual classroom" environment described above allows access to course materials by students who could not otherwise take the desired courses. This realization offsets some of the real or perceived disadvantages of taking online courses via ALN's. On the other hand, the rich set of information sources embedded in the ALN design described in this paper provides an appealing environment with high-quality slides and images of handwritten notes synchronized with the streaming video and audio. The mailing list and electronic conferencing facility allow collaborative interaction with other class members as the lecture is being viewed and this captures the desirable benefits of a network or people—albeit asynchronous in time and space—learning together.

IV. Comparison with Similar ALN and Streaming Media Projects

Our survey reveals three (3) reliable choices of streaming software technologies:

1) *The Real Producer Suite* of programs from real Networks (formerly Progressive Networks), which is the choice that we made at the University of Florida partly due to the good quality of the product as well as the limited free distribution of the client and the server modules and also the modest cost of the full version.
2) *VXtreme Web Theatre* from Microsoft, which is the technology selected by Stanford University. The video and audio quality are comparable to the Real Networks product, however the server version of this software is quite costly. The more recent Microsoft Media product is very similar to the Real Producer Suite.
3) *VDO software*. Our investigation suggested that this choice is not very popular at this time.

In what follows we summarize the results of a brief survey of ALN and streaming media applications at three leading universities: Stanford [8], Purdue [9], and University of Illinois [10] at Urbana-Champaign. A lab at UIUC has developed the concept of "a virtual classroom" into a single unified format and this format is used to offer more than 400 online courses. However no streaming technologies were available at the time we audited their site. For Purdue University there was no standard format for the classes available online and the outreach program mostly focuses on video delivery for in-state students. Stanford University's distance education offers comparable synchronized lectures to that described in this paper but without some of the interactive features found in the UF model. Stanford uses the VXtreme streaming media technology and our assessment was that the video and audio quality was comparable to the one we obtained with the RealMedia system.

The experience gleaned from the hybrid synchronous asynchronous delivery of the Computer Communications course at the University of Florida is being leveraged to offer an entire BSEE as well as a complete Master of Science program online. These programs are being developed with funds from the State of Florida, the National Science Foundation and the Sloan Foundation. Several courses in this program will be available in Spring 1999.

V. Future Work

The prototype system for hybrid synchronous and asynchronous learning environment described in this paper is still in the process of development and refinement as we gain more experience and assess our preliminary effort in terms of teaching and learning effectiveness.

From a cognitive point of view, the most important challenge is to bring together the educational content that students can access in both synchronous and asynchronous modes and to unify their respective pedagogical approaches. This merger is possible if an integrated educational approach is taken. In such an approach, the expositive teaching and active learning activities should be combined and balanced according with their respective pedagogical objectives, their didactic efficiencies, and technical constraints [11].

Seven different activities can be distinguished in that perspective. First of all there is the *lecture* which is a phe-

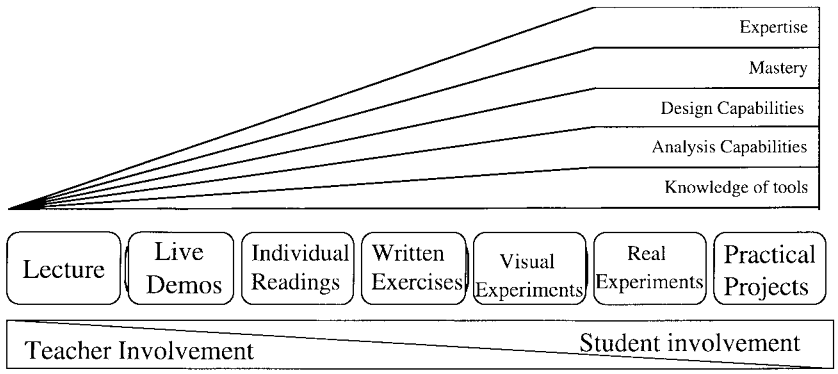

Fig. 4. Pedagogical activities in integrated education.

nomenological approach convenient to bring a synthetic view of the field and to underline important topics. Then there are *demonstrations* which serve as examples for motivation purposes. In addition *individual readings* provide access and deepen knowledge in a specific area. *Written exercises* are necessary for mastering related mathematical tools while *virtual experimentation* done by simulation serves to reinforce the understanding of the subject matter in a versatile manner. *Real experimentation* is indispensable (especially in certain branches of science and engineering) for developing professional intuition and skills to deal with physical processes and instrumentation. And last, but by no means least, *practical projects* provide the framework for the acquisition of the right methodology to cope with real-world problems. These activities and their peculiarities are described in Fig. 4 which suggests that the instructor's direct involvement should be reduced to let students act as much as possible by themselves.

In a hybrid synchronous and asynchronous learning framework, the lecture can be taken live or later by playing the archived audio/video stream. In either case, with much of the traditional class material already on-line, lecture segments could now be reduced to the more desirable length of about 15 min, which is consistent with the defined pedagogical objectives. The extra time can then be used for the other active learning modes such as interaction and collaboration which are often neglected in traditional education. To enhance and to support additional personal readings, printed documents or textbooks can be converted to an electronic form. Documents in PDF or HTML formats can nowadays be produced easily with commercial software or converters (LaTeX to HTML for example) and new standards such as MathML for describing mathematical expressions in WWW pages are already beginning to emerge [12]. Electronic documents offer the advantage, that while keeping the sequential structure of printed documents, they can be enriched by dynamic links and search capabilities. However, recent research shows that a better pedagogical efficiency can be obtained if a new structure for the internal relations inherent in the subject matter is chosen for the electronic version [13]. Remote manipulation of training resources is another paradigm which can be developed in the proposed hybrid learning framework. For example, synchronous demonstrations on remote facilities can be performed by the teacher and watched by students. Asynchronous real or virtual experimentation can be conducted using physical hardware at a remote location [1] or interactive simulators.

From a technical point of view, it is anticipated that several new or refined features will be added to the system in the near future. These include a more effective (and possibly voice-based) system for live feedback from remote students. Another feature which requires some more work is a "web-cam"-based system for sending at regular intervals high quality images of handwritten documents to remote students via a specific URL. Finally we hope to investigate the use of a speech-to-text system for converting the lecture's speech to a text stream for real-time scrolling and archiving to a text file and/or WWW page.

VI. Conclusion

There is no doubt that the hybrid synchronous and asynchronous learning environment will revolutionize our way of learning as well as teaching in the near future. By overcoming the distance and time constraints, we are not only broadening our audiences but offering the opportunity to learn to people everywhere in the world who may otherwise have had no access to these educational resources. By opening new horizons to working engineers, offering them a chance to improve and enhance their knowledge, we are building one more bridge between the academic community and industry. The pedagogical content as described in this paper for the hybrid synchronous and asynchronous environment is in a convenient form to be integrated into a CD-ROM or in WWW-based courses offered by "virtual universities."

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