Experiences in the Use of New Technology in Engineering Education

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Abstract *- This paper describes the experiences of the authors in the delivery of engineering education with the help of three different technologies. These include the use of videoconferencing and CD-ROM technology for distance education and the development of World-Wide Web materials for resident instruction. The hardware and software for each methodology is described. The advantages and disadvantages of each of the methods is discussed and the benefits for the student and instructor and summarized.*

Introduction

Penn State has been involved in distance education since 1892 when the first correspondence courses were delivered to farmers by regular mail. Television classes have been offered through cable television (PENNARAMA) since the 1970's. Today, distance education still uses these media: but, the advent of videoconferencing and personal computer technologies as well as the widespread use of the Internet and World Wide Web (WWW) materials has changed the face of distance education. In this paper the authors describe their experiences with three different delivery techniques and technologies: videoconferencing, WWW class materials and CD-ROM technology. References 1 and 2 describe some of our previous efforts at teaching using technology.

Video Conferencing Based Teaching

Practicing engineers need access to continuing education to remain abreast of new developments or for retraining. For these potential students, resident instruction is usually not an option. With the cooperation of their employers, we have been making courses available to employees in the workplace through the use of two-way interactive video. In this section the types of hardware used in the videoconferencing courses are described briefly. The software applications used to generate class materials are also discussed. In addition, our experience with different types of course material is also described. Finally, the benefits to both the student and the course-provider are discussed.

Distance education by video at Penn State is based on both satellite and videoconferencing technologies. Penn State bases its standard interactive videoconferencing on equipment manufactured by the PictureTel Corporation. Both conference room and television studio facilities are available.

Figure 1. View of Videoconference Room. 120 Barbara Building

Figure 1 shows a typical videoconference room. The instructor sits in the foreground with the PictureTel control panel and the document camera within easy reach. Any on-campus students sit at the conference

table and there are two large-screen monitors at the other end of the room for either local or remote views.

Figure 2: View of Studio Facility. Studio C Mitchell Building

Figure 2 shows a studio facility. In the videoconference room the instructor usually controls the selection of cameras. Though it takes a little time for the instructor to become comfortable with this set up, it is not particularly distracting. In the studio facility, a producer controls camera selection and all aspects of the transmission. In both cases, the instructor is able to view monitors that display the class at the remote site as well as the materials that are being transmitted. A standard configuration at the receiving site would include monitors, cameras, speakers, a document camera and associated electronics. A recent quotation for this equipment was approximately $28,000. With the use of a video bridge it is possible, subject to a short time delay, for all participants in the class to see and hear each other. Penn State has a video bridge that accommodates up to sixteen calling sites. All transmissions run at 2x56Kbps. The cost is roughly $30 per hour per remote site connection. With the use of compression technology this gives a reasonable picture at the receiving site: but, rapid motions tend to be blurred. The instructor can manipulate the remote camera to enable the viewing of any materials or students at a remote site. The Penn State web-based guide to video conferencing is at **Error! Bookmark not defined.** .

Since the quality of broadcast is not yet up to that of regular television transmissions it is essential that the instructor takes time to prepare both class notes, to be distributed to the class prior to the class time, as well as materials for use during the class. This is perhaps the most important aspect of this delivery system. One author (PJM) has tried several methods. It should be noted that the class being described is a graduate class in aerodynamic noise. It is heavily theoretical in nature with many equations to be developed and applied. During the analytical development there is little opportunity for interaction with the students, except for points of clarification. The first time the course was offered handwritten notes were distributed to the class and important equations and figures were prepared in large type for use with the document camera. The instructor then went through the analysis by writing the development on large pages viewed by the document camera. Though the students found this method satisfactory, so long as the instructor's writing was large enough, the neatness of the notes left something to be desired. In subsequent course offerings the notes were typed the using an application called Scientific Word (**Error! Bookmark not defined.**). This is a graphical interface between the user and a LaTeX document. Many styles are available for the typesetting, and the author modified a notebook style to give a two-inch margin on the page to allow for note taking. The author has now adopted this method of producing class notes for all his classes: whether they are resident instruction or distance education. With so much analysis and equations the author has found it to be more time effective to do his own typing. Though the initial time commitment is considerable, once the materials are prepared, modification for subsequent course offerings is trivial. In the future these notes will be made available to the students on the World-Wide Web.

The lack of physical personal interactions can make the class somewhat impersonal: especially if the nature of the material makes communication primarily one-way. Several methods can be used to overcome this, apart from the usual breaks in the class for questions and discussion. Penn State includes site-visits by the instructor in many of its distance education contracts. This is usually for sites with a significant number of students. This affords an opportunity for the instructor to meet with the students, to discuss the coursework, and to view the work-site. This can lead to the inclusion of additional course materials that address some specific application relevant to the students. As part of the coursework, the students are required to work on a term paper. The site-visit provides a chance for detailed discussions of the choice of topic or progress. An unexpected benefit of the visits is the chance for interactions with supervisory personnel. For the instructor, this provides contacts for potential employers for graduates, as well as research or consulting opportunities.

World-Wide Web Based Teaching

All of the approaches discussed in this paper require significant investments in computers, software, networking, technology classrooms, and other equipment. All of this is expensive, but it is essential for educating the modern engineer. You simply cannot teach modern engineering effectively with a chalkboard alone.

Penn State has approximately 20 technology classrooms on campus. Most of these have networked Windows NT

computers in a podium specially designed for the classroom and a ceiling mounted high-resolution projector as shown in
Figure 3. It is crucial to have dimmable lights and window covers (preferably drapes). Since these rooms are never locked, they also have fiber-optic security/alarm systems, which are connected to our police department. The most crucial feature for these rooms is high reliability. Faculty

Figure 3. View of Technology Classroom: 215 Hammond Building

will not adopt this technology if it is not reliable, and the students will get very frustrated if the equipment fails even once during the semester. This is difficult to realize in practice, since there are numerous components which can (and will) fail, including the projector, the software, the computer, the network, the mouse, etc. These machines must be considered 'mission critical,' and failures must be minimized through redundancy, low-maintenance solutions (e.g. Networked Computers or X-Terminals), and rapid response support teams. Each of our technology classrooms has a telephone connected to the audio-visual department, and they can respond in a few minutes (but cannot always fix the problem in that short a time). Since these components are so critical, redundancy is important. While this increases the cost, one must consider the cost of a cancelled class session, especially in a large classroom. Additionally, faculty will not adopt this approach widely if they need to have non-technology lectures available in case of equipment failure.

With virtually all of our students having access to the World-Wide Web, more and more course material is being developed for this medium. There are several advantages to the preparation of class materials for the Web. Not of the least of which is the multiplicative nature of links within the main document. This means that the student has access to the equivalent of many textbooks, class notes, and historical material. These may include example problems, exercises, animations of solutions, audio files, movies, technical references, sample programs, databases, and news items. Another advantage is that the material can be kept up-to-date, even though a field may be progressing very rapidly. Printed copies of notes could be out of date within one to two years: however, one should not compare textbooks to Web material, since the media are so different. With the ability to add animations, audio, and live demonstrations, one can teach the course in a very different manner, and cover completely different material

One very curious phenomenon, that was not foreseen, was the student's almost unanimous desire to print out the Web pages. This is ineffective since the pages change often, and all the material cannot be printed (e.g. animations, large databases,…). Many faculty have laptops and continuous access to the Internet, and therefore do not need to print out Web pages. The students usually find themselves disconnected from the Internet quite often, such as between classes or even at their residences. This problem has been addressed by:

1. Providing Ethernet networking to all dormitory rooms.
2. Providing approximately 900 modems (24 or 33 Kbps) for dial-up access
3. Providing approximately 1200 computers (mostly Windows NT machines) in student laboratories

In the Fall of 1998 we will begin offering these notes to the student on CD-ROMs, which we can produce ourselves for a few dollars each. It is expected that more and more students will rely on laptops in the future, and this need must be addressed in our classrooms and in our course materials. In the future it will be essential to provide continuous access to the Internet for students. We may well evolve to the point where the students and faculty carry laptops with wireless Internet connections. Penn State already has several of these operating. Also, using microwave antennae one can provide high-speed access over a range of several miles. Clearly, higher education teaching and learning is under-going a dramatic change due to the incorporation of computer technology. Marshall McLuhan's discussion of 'the medium is the message' [Ref. 3] is as appropriate now as it was 20 years ago: if not more so. It would be very foolish to underestimate the effect the Internet will have on higher education.

One of the authors (LNL) has made extensive use of the Web in his courses. Virtually all of his recent course notes are available on the Web. Some of the courses are:

1. Introduction to Computational Fluid Dynamics (**Error! Bookmark not defined.**
2. Introduction to Parallel Computing for Engineers (**Error! Bookmark not defined.**
3. High Performance Computing Hardware and Software (**Error! Bookmark not defined.**)
4. High Performance Computing Seminar (**Error! Bookmark not defined.**)

These are all very different courses, but the use of the Web greatly enhances the educational experiences in each case.

The first course is designed to teach the various algorithms used in Computational Fluid Dynamics (CFD), by showing how they work on various model partial differential equations (PDE's). In this course, we discuss PDE's and algorithms in class almost every day. In the past, this was done on a blackboard, and the students had a difficult time copying the equations and also trying to understand them. Such an approach now seems archaic and very inefficient (and the use of transparencies is only slightly better). With the tremendous advances in word processing software, it is now possible to type in all of these equations using Microsoft Word or PowerPoint. As noted above, while it does take a little more time to type the notes than to write them on paper, this only has to be done the first time the course is offered. In subsequent offerings of the course one simply has to update the class notes. In addition, in lengthy mathematical derivations, one quite often makes incremental changes from one equation to the next. Therefore by cutting and pasting, the entering of the equations actually goes quite quickly. All of these notes can then be put easily on the WWW. We usually use PDF format, but have had quite a few problems with this format. Another, perhaps better, way to do this is to simply convert the PowerPoint slides to HTML. This is not meant to encourage "shovelware," where old lecture notes are merely copied into the new medium. If one really uses the new medium and all the new options it gives you, the notes will not be the same, and they will be heavily supplemented with multimedia and 'live' software demos. There are also excellent textbooks in CFD, so only key equations need to be presented and discussed during class, the notes are not meant to be a substitute for the textbook.

This course also requires numerous programming examples in order to illustrate the behavior of the various algorithms applied to the PDE's. Again, doing this using a blackboard is very tedious and ineffective. The modern version of this course uses MATLAB demonstrations in class, including animations of the solutions. One could spend an entire lecture trying to explain numerical stability, but a simple MATLAB program will show exactly what happens to the solution when the algorithm is unstable. If a picture is worth a thousand words, an animation must be worth a million.

One of the main messages we wish to deliver here is that Web-based teaching does not necessarily mean that class preparation will be much more time consuming. On the contrary, we feel that after a fairly short learning curve, faculty productivity is greatly enhanced. There are a wide variety of approaches to Web-based teaching, from simply putting old copies of text-based notes on the Web to developing special purpose animation packages to illustrate a difficult concept. We are advocating a middle-ground approach. Most faculty are very, very busy and cannot devote more than a 4-8 hours preparing each new lecture. It is not necessary to develop special purpose software. Through the use of common software packages (Word, PowerPoint, MATLAB, Mathematica, Tecplot, RealPublisher, Premier, Acrobat, etc.), one can dramatically increase the efficiency and productivity of the classroom. We need to realize that future generations of faculty will find this medium very natural and straightforward. In addition, distance education and life-long learning will increase in importance over the next few years, and Web-based courses are an excellent basis for distance education.

The second course listed above (parallel processing), is quite different than the CFD course. In this course we teach students how to use the latest parallel supercomputers. While traditional CFD algorithms do not change that rapidly, every time we teach parallel processing the material is quite different. Having the notes on the Web makes updating the material and refocusing it to the latest hardware and software quite easy. In addition, virtually every thing you need to know about parallel processing and supercomputers is on the Web at sites around the world. It used to be very difficult trying to collect all the latest information on computers, now it simply means adding the appropriate link to the notes. While this course does not involve many complicated equations or algorithms, the Web is the natural medium in this case for other reasons. One of the important features for this course is having the ability to log onto a remote supercomputer during class. Trying to explain how to use these systems without having live access is ineffective. In fact, for several of the class sessions we meet in a room where all the students have computers as shown in Figure 4.

Figure 4. View of Computer Laboratory: 316 Hammond Building

The third course listed above consists of 15 lectures, all Web-based. This is a one-credit course designed to teach incoming graduate students some of the main software tools used in high performance

computing. This course is valuable to not only the students who enroll in it, it is also used by hundreds of people as a Web-based resource. In addition to all of the notes being on the Web, we have recorded the lectures (audio format) and those are on the Web as well. This is very straightforward. One can use a normal tape recorder or video camera to record the audio, and then use RealPublisher and a PC to produce Web-based audio files in minutes. The audio files are typically 7 megabytes in size for a one-hour lecture. Faculty and students often cannot attend a lecture if it is only given once at a specific time. Now they can listen to it at their convenience, at home or in their office. It will not be long before complete video collections of lectures will be on the Web as well.

The fourth course listed above is also quite different than the others. This is an invited lecture series, with roughly one-third of the lectures given by invited visitors to Penn State. These lectures typically do not have Web-based notes associated with them, but the complete audio recordings are made available on the Web. These are resources that will increase in value as the years go by. It is not often we have experts discussing their research to a general audience, and we have the ability to revisit it years after the event. These are usually very candid lectures, and often have lots of questions from the audience.

These Web-based resources only serve to supplement the course content provided by the course instructor who provides lectures, discussions, exercises, homework, tutorials and examinations. This also frees the instructor from the personal development of some educational materials that are widely available. We are now seeing unprecedented sharing of lecture material.

CD-ROM Based Teaching

Recently one of us (VWS) has become involved with the development of a sequence of courses to teach Noise Control Engineering to practicing engineers at a distance [Ref. 4]. The project is funded, in part, by the Alfred P. Sloan Foundation and is a collaboration between the Penn State College of Engineering and Penn State Office of Continuing and Distance Education. Many people, too numerous to list, have been involved with the development of the Noise Control Engineering courses, and the experiences related here are those of the one of us generating the course materials. Specific information on the courses may be found at **Error! Bookmark not defined.**.

Because the students interested in Noise Control Engineering are spread geographically across the United States, it is not cost effective for each student to travel to a central site, or group of sites, where satellite broadcast transmissions can be received. Instead the students are busy working professionals who have limited time. Further, the students often have severely limited Internet connectivity from their workplace or home. A typical student may wish to access course materials from behind his company's Internet firewall, making direct Internet access difficult or impossible. On the other hand, one would still like students to have access to materials deliverable via the Internet and allow for group collaborations on engineering problems. This project was funded by the Sloan Foundation to determine how to best encourage geographically dispersed students to work together and collaborate in teams of "cohorts."

After several false starts the decision was finally made for the Noise Control Engineering Project to place all of the study materials directly on a CD-ROM on each student's computer instead of making them available over the Internet. The materials are accessed using a standard WWW browser, but a student can look at the materials offline. There are two major benefits of this methodology. The first is that the student's course material access is almost instantaneous, since no slow Internet connections separate the student from the materials. This is a particularly important feature for the distance education student since their only connection to the Internet may be via a slow modem. The second consequence of using the CD-ROM is that the student or his employer (depending on who pays for it), will have minimal communications connection charges. This again can be very important if long distance telephone connections are required from remote sites.

Each CD-ROM contains lesson materials (lecture notes), figures, QuickTime animations, sounds, study questions, and reading assignments for designated course texts. All of these components are accessed via a WWW browser. In addition, the CD-ROM also contains MATLAB scripts as well as executable LABVIEW virtual instruments and interactive animations. The participants complete MATLAB assignments throughout the sequence of courses as well as interact with other students and the course instructor via the FirstClass conferencing/E-mail software (**Error! Bookmark not defined.**).

It was identified early in the design of the Noise Control Engineering program that student collaboration would be important. It proved to be a significant challenge to develop methods to encourage students with disparate schedules to collaborate synchronously. The model adopted was to have students use the FirstClass software to engage in bulletin board conferencing in a highly structured environment. Each homework problem set and lesson in the sequence of courses has its own area for student discussion, and students are required to collaborate with each other in problem solving. The decision to go with a commercial software program, rather than just ordinary E-mail, was to highly structure the student interactions with each other and with the course instructor. Further by restricting the student interactions to one particular conferencing program, the course instructor and university computer support personnel have an easier job of supporting that program.

The actual course material, replacing the lectures of in-residence courses, is provided in Adobe Acrobat (PDF) format, translated directly from each lesson author's word processor. The Adobe Acrobat documents are readable via the WWW browser. Acrobat allows for direct hypertext hot linking, as does hypertext markup language (HTML). After receiving the text of a lesson from its author, the text is converted to Acrobat, and the figures, animations, and sounds are inserted, possibly cross-linked to other introductory or explanatory pages written in HTML.

One reason why Adobe Acrobat was chosen for the presentation medium for the lessons was that equations are easily legible in this format. Since the language of HTML does not include equations and Greek characters (this may be available soon), one must represent equations as embedded GIF files in the HTML document. A pilot study for this program employed the program Latex2HTML to convert Latex documents to HTML files including GIF files for the equations [Ref. 5]. The latest versions of popular word processors now also have the capability of writing out HTML files with embedded GIF files for the equations. However, the quality of the equations as seen in the GIF files is not as good as one would desire. In addition, moving and renaming all of the crosslinked individual files created for such an HTML document into the proper locations for course delivery on the CD-ROM was a nightmarish procedure. The Adobe Acrobat presentation method eliminates the large number of GIF files needed for each equation, and the quality of the equations is high. The methodology of using Acrobat was suggested and implemented by Tom Iwinsky of the Penn State Center for Academic Computing, and it has been successful for the present project.

One of the advantages of learning about noise control including the principles of acoustics and vibration is that objects vibrate and particles move. Hence, animated QuickTime movies are an excellent vehicle to provide concept demonstrations for students. One of us (VCS) has developed a number of animations for acoustics education that are available over the WWW at,

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These are the types of animations that are directly available on the CD-ROM integrated into the lessons in Acrobat format. The animations are created using the symbolic manipulation program Mathematica. A discussion of how these animations are created was presented recently [Ref. 6]. Examples of single frames from two animations are shown in Figures 5 and 6. Figure 5 shows the modes of vibration of a square membrane and Figure 6 is a schematic of a Helmholtz oscillator.

One observation made in the development of the course materials is that the quality of the lessons must be very high, considering there is no faculty member present when the student views them. These lessons, for the most part, must speak for themselves. (Early in the planning of these courses it was decided that no "talking head" picture of an instructor would simply read the course materials to the student because this method has been found to be boring to students as well as to drive the production costs up substantially.)

To maximize the quality of the presented lessons, each author's contributions are peer reviewed by other faculty members involved in the Noise Control Engineering courses. Although this procedure ends up with materials having the benefits of the experiences of many faculty, the development of the lessons is slow. For many faculty not accustomed to working with a team of individuals in the development of course materials, it can be stressful going through this review process. Fortunately, however, the students viewing the lessons can be assured that every effort has been made to insure the correctness and validity of the presented Acrobat documents.

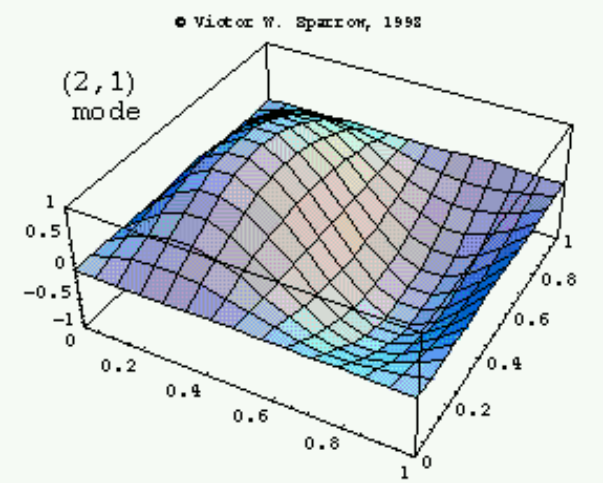

Figure 5: Single Frame From Animation of the Vibration of a Square Membrane.

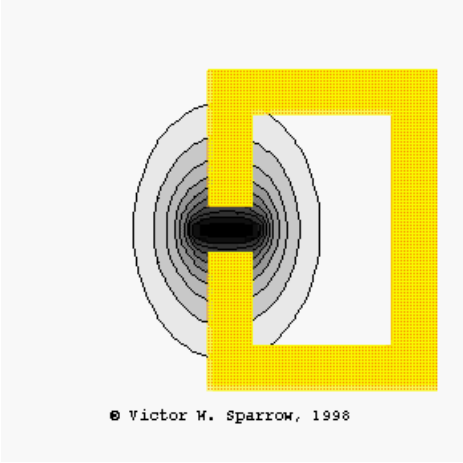

Figure 6: Single Frame From Animation of the Operation of a Helmholtz Oscillator.

In summary, the delivery of the Noise Control Engineering courses for practicing engineers via CD-ROM has been very successful using the methods described here. However, the technicians and engineers who participate in such courses are often very bright and computer literate. They expect high quality in both the course materials and in their presentation. A faculty author interested in teaching distance education students using this model should be prepared for a substantial commitment of his or her time to produce instructional materials meeting students' expectations.

Conclusions

This paper describes several recent attempts at the use of technology to teach engineering. The information age is changing virtually every aspect of life. Teaching and learning is also undergoing incredible changes. It is especially important for engineering educators to adopt to these changing times. Computers, software, information technology, and the World-Wide Web are essential aspects of modern engineering. It is very artificial to teach engineering without using the tools of the trade. Resident and distance education can benefit from the new technology. But we have tried to illustrate that the needs of resident and distant students are different, and the teaching also requires varied approaches.

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