

Web based instruction in engineering

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Every century has brought significant events that have changed our lives. In the 19th century, the Industrial Revolution changed the way we produced and manufactured goods. In this century, man has been able to do amazing feats, especially in the field of engineering, such as learning how to fly, breaking the sound barrier, suspending satellites in geocentric orbits, flying to the moon, and so forth. But, perhaps, the most remarkable achievement that has affected humanity is the ability to instantly communicate and exchange information with anyone at anytime, anywhere in the world. This medium is known as the Internet. We refer to the Internet as the Information Revolution. The Internet has eliminated distances that once kept people apart. There are no frontiers or boundaries anymore. Everything that is on the network is easily accessible from everywhere in the world (the middle of the desert, the ocean, the north pole). Where we can't string cable to distribute information, we can setup a satellite dish and bounce information to the far reaches of the earth. As with any new technology, people will always find a way to benefit from it. Whether benign or malignant, worldwide economies, political and religious beliefs, entertainment, or education will be affected. In this article, we

will focus on the impact the Internet is having in the field of education, more specifically, in the field of research and engineering. We will also examine the Internet's benefits to learning and what it means to teach on the web. Lastly, we will explain how to design instructional material for teaching on the Internet.

“Web based learning techniques” refers to the decentralized method by which material is delivered on the Internet. Instead of attending classes in a centralized institution or location, students sit in front of a monitor viewing, listening and interacting with class materials that have been designed for that purpose. Various components are incorporated into the class materials so as to mimic and enhance the real live experience of a classroom. Video and audio segments of the professor lecturing, for example, may discuss specific topics more in depth.

In a classroom, when a student has a question, he or she raises his or her hand and immediately grabs the professor's attention. This is the student's first line of communication. On the web things do not happen quite like this, but there are several effective ways to communicate with the professor, teaching assistant, and classmates. By means of “asynchronous” communication tools such as email, bulletin boards and chat rooms, or even synchronous videoconferencing, a student can maintain contact with the instructor and fellow classmates.

An electronic textbook is added as the core reference material for the course. This is in no way a substitute to the traditional textbook, but it offers different advantages over its paper-

bound counterpart. The entire electronic book is created with an HTML (HyperText Markup Language) editor. Plainly put, this is a program that “marks-up” language (very similar to a word processing program such as Word, WordPerfect, etc. to **bold**, *italicize*, underline, increase, decrease font size and change font type on a text document). HTML is plain text - ASCII characters - and one may use any word editor, such as a basic Notepad application, to create HTML content. HTML also allows one to incorporate rich media: photos, drawings, video, audio, animation, interaction and, more importantly, hyperlinks. Hyperlinks allow students to click on an area of the document and immediately be transported to the previous or following chapter, to additional references (no more page turning), to bookmarked pages, to an audio explanation by the professor, to a graphical representation of the problem being discussed, or to other relevant sites.

You may ask yourself, why use HTML and therefore have to learn a programming language? You don't have to learn HTML because the text-editor will translate to HTML for you. Simply consider HTML as an encoder, a universal container in which you put your information. You use the Internet as your information superhighway and you use a web browser (Netscape, Internet Explorer) to unpack, decode the HTML content. Simply put, HTML is the universal language of the web; whoever creates information must do it using HTML so that anybody has the ability to see it with a simple web browser without requiring specialized tools. This electronic textbook can be updated and published on the web immediately. This is a significant benefit since current research and development require that material be updated frequently. Updating conventional printing materials can be expensive, and they become easily outdated.

The students will have access to multi-media rich material. Figure 1 shows an actual web page of an engineering class that contains lecture material prepared using text with hyperlinks, audio with additional explanations, and two interactive pictures that can be arbitrarily rotated to help understand the three-dimensional configuration of two crystal lattices.

The screenshot shows a Microsoft Internet Explorer browser window with the title "LECTURE 13 - Microsoft Internet Explorer". The address bar is empty. The menu bar includes File, Edit, View, Favorites, Tools, and Help. The toolbar contains Back, Forward, Stop, Refresh, Home, Search, Favorites, History, Mail, Address, Go, and Links. The main content area displays the following text:

LECTURE 13

SILICON ANISOTROPIC ETCHING

Diamond Lattice: is the crystal structure of silicon, and germanium. The lattice can be visualized as two intersecting Face Center Cubic Lattices, offset by $a/4$ in the x,y, and z-directions. Visualization of the [diamond lattice](#) is shown with the [Chime Plug In](#). A diamond and a face center cubic crystals structures are shown below. Here are two very nice views for the Diamond lattice([1](#), [2](#)).

Diamond Lattice

Buffering (101.2 Kbps, 1 sec)

The bottom of the page features two side-by-side images. The left image shows a collection of white spheres representing atoms. The right image shows a 3D ball-and-stick model of a diamond lattice structure, with atoms represented by white spheres and bonds by yellow and pink lines.

FIGURE 1: Example of an actual web page demonstrating the use of different media.

Assessing the progress of students on the Internet is similar to the conventional classroom. Homework is posted on the web and must be returned electronically to the instructor by email. Exam assessment might be done electronically (replacing the #2 pencil assessment forms), but with the present technology it is safer to do it the old fashioned way in a classroom. For security reasons, mid-terms and finals should be administered by a proctor. For those students living far away from school, arrangements can be made with local universities, industries, embassies, etc.

Some Advantages

Web-based learning is beneficial for those students who cannot attend classrooms because of their personal or professional commitments, or their limited financial resources, or physical limitations. The worldwide nature of the Internet brings together in a class a cornucopia of cultures, backgrounds, levels of understanding, communication, collaboration, and expertise. As a whole, all participants in a class, including professors, have something to learn. Professors will learn from the students and receive immediate feedback about their content. It will also be useful for those students who are shy and afraid to ask questions in public. Another advantage is accessibility. Instructional material is available 24 hours a day, eliminating conflicts with one's schedule. Because the instructional material is always available, learning is self-paced. From the point of view of instructors, once the class material is in electronic format, it's easy to modify and keep up to date. In addition, the organization of the material will be enhanced because there will be only one repository for everything.

Design of a web class

Having introduced the advantages and the potentials of the Internet as an educational tool, the next step is to look at how instructional material can be designed for delivery on the Internet. In order to design effective class material for all students, one needs to take into account different learning styles. There are four different ways of learning: visual, audio, reading and writing, and interactive (examples are provided at <http://www.uic.edu/eng/meng>). Therefore, one needs to prepare materials with the four learning styles in mind.

Visual Learning

A video can either be created by using a video camera or software. It is very effective for showing animated scenes, such as an airplane taking off. The drawback, however, is the large amount of data that has to be transmitted for the images. Even with the use of compression techniques, the bandwidth required to ensure a good quality of the service is nowadays still too large for the communication speed available to most users. The phenomenon of congestion on the network (so-called net-congestion) is very frustrating. It occurs when the electronic traffic is too elevated and causes a video to stop randomly. Our advice is to use video only when absolutely necessary.

An interesting kind of video, that is also interactive, is produced by QuickTimeVR (<http://www.apple.com/quicktime>), where a three dimensional object can be seen from different view points. Quick Time VR is used to connect a set of pictures so that a user, by means of a mouse, can rotate the objects in a three-dimensional space.

Video animations can be created by software packages such as Chime (go to <http://www.umass.edu/microbio/chime> to interact with three-dimensional structures of molecules), Ansoft Maxwell (go to <http://www.ansoft.com> to view an interesting animation of the electric field in a spark plug) and Hewlett Packard's High Frequency Structure Simulator (go to <http://www.tmo.hp.com/tmo/hpeesof/products/hfssdemo/coax2.html> to view the animation of the optimization of a coax transition). These software packages are mainly meant for designers, but they also help to visualize difficult concepts and are, therefore, useful to web learning.

Audio Learning

Audio can be created either by recording actual sounds or by producing them from software. Bandwidth requirements for the audio are not as demanding as those for video. In addition, audio can be compressed and reproduced while maintaining good quality of the sound. Both audio and video can be played using streaming techniques. *Streaming means that the media files are kept in a central server and are distributed on request to client computers. The distribution is performed in such a way that the media file is played before it is completely received. Each client must carry a copy of the streaming software that divides the media file into chunks, whose size is determined according to the transmission speed between the central server and the particular client. The local computer does not keep a copy of the media file; it just plays it.* Examples of streaming software that run on clients are RealPlayer (<http://www.real.com>) and Quick Time (<http://www.apple.com/quicktime>), which are all free of charge.

Reading/writing learning

Text is the easiest material to prepare for computer-based learning. Text on a computer can be easily improved, compared to the *paper version*, by taking advantage of HTML and hyperlinks. It can be prepared to look like a book or a set of slides. For book-like format, many word processors now have the capability of creating HTML, even though the fine formatting is lost in the HTML version of the document. Another way is to produce a Portable Document Format (PDF) document, which is like an image so that the formatting is exactly preserved. Since mathematics is often included in engineering classes, one needs to use the appropriate software. For many years, mathematicians have been using a typesetting document system called TeX or the more recent version called LaTeX (<http://www.ctan.org>). TeX and LaTeX do not create any HTML code, but this is easily done by a translation package called LaTeX2HTML. TeX, LaTeX, and LaTeX2HTML are all available free of charge and run preferably on Unix systems. Beyond word processing systems there are mathematical packages, such as Mathematica (<http://www.mathematica.com>), Maple (<http://www.maplesoft.com>) or MathCad (<http://www.mathsoft.com>), that are mainly developed for computational applications, but also offer a feature to create documents and export them into HTML.

Another possibility is to write lectures using slides that can be easily prepared with, for example, Microsoft PowerPoint (<http://www.microsoft.com>), or Corel WordPerfect Suite 8 (<http://www.corel.com>). In addition, one should keep in mind that any document already existing in electronic format can be easily published on the Web.

Interactive learning

“Interactive” refers to learning by doing something. For engineering classes, it is becoming more frequent the use of interactive programs to show various kinds of results. Examples might be the behavior of a chemical plant (students define the characteristics of the plant and observe its performance), the electromagnetic field distribution within a waveguide (students define geometrical parameters of the waveguide and understand the field distribution that is created), the three-dimensional structure of a crystal lattice. Whenever one of such interactive tools is available on the web, it can easily be linked to the class notes, for the benefit of the students.

Putting things together

Once the individual lectures are ready, they can be uploaded to the server, or they may be graphically improved by using web publishing tools such as Macromedia Dreamweaver or Flash (<http://www.macromedia.com>) and Microsoft FrontPage.

An online class requires a management tool that helps to organize the lecture material, communicate with the students, and keep track of grades. Examples of such tools are CourseInfo (<http://product.blackboard.net/courseinfo>), WebCT (<http://homebrew.cs.ubc.ca/webct>), TopClass (<http://www.wbtsystems.com/solutions/products.html>), and Lotus Learning Space (<http://www.lotus.com/home.nsf/welcome/learnspace>).

About assessment

Some of these web management tools let you create simple multiple choice quizzes that are automatically graded by the system when the student submits the quiz. More sophisticated kinds of assessments can be prepared using Mallard (<http://www.ews.uiuc.edu/Mallard/Overview>).

Synchronous Conferencing

In this article, we have dealt mainly with asynchronous teaching, because that is one of the advantages of letting everybody to proceed at his or her own pace. However, there are also tools to handle teaching through synchronous conferences on the web, such as First Class (<http://www.uic.edu/depts/and/firstclass>).

Hardware/Software requirements

Now that we have considered all the components, what are the costs? What kind of people and equipment are required? The advantage of a personal computer is its ability to allow you to do numerous things, and a basic multimedia computer will allow anybody to create most of the different types of media for your class. A middle-end multimedia computer of \$1500 will even allow you to digitize your audio. For incorporating other types of media you will need input devices. Some of the most popular types are:

- Scanner: \$100 used for digitizing photos, graphics, etc.
- Digital Still Camera: \$300 used for taking digital photos.

- Video Camera and Video capture card: \$400. You'll need this if you are planning to incorporate video. You may use your existing video camera, but you will need a video capture card to digitize the video.

All these devices come bundled with software that will allow you to manipulate your content.

For large development and production projects, we recommend higher-grade workstations, professional input devices, and a dedicated development team. All of this, can increase the cost considerably.

For publishing your materials you will need a server and a high speed connection to the internet. A regular PC hidden in the back of your closet can act as a server, but you most likely want dedicated servers and personnel to monitor and deliver your materials reliably over the web. This is where your academic institution's computer center can greatly help you cut costs and headaches.

Most Higher Education institutions have recognized the benefits of online learning and have invested time and resources to encourage its development. Some have created centralized laboratories where professors receive guidance on how to develop their classes. To help cut costs to individuals and colleges, they offer free of charge all the necessary resources (hardware, software, input devices, servers, etc) to produce and deliver an online course.

UIC – College of Engineering: A case study

In the Fall Semester 1999, the College of Engineering of the University of Illinois at Chicago (<http://www.uic.edu/eng/meng>) initiated a Master of Engineering degree, which is offered entirely online. Many potential students, who already have a Bachelor's degree, have been unable to realize their educational dreams because they reside in a remote geographical area, or have work or family obligations that do not allow them to pursue their educational goals in a synchronous classroom environment, or because of a disability. The web site for Master of Engineering is managed by CourseInfo. The class material is delivered to the students by means of video, audio, and text, according to what is more appropriate. For example, a theoretical class such as Electromagnetic Field Theory is based on slides that provide an outline of the class. Associated with each slide, there is an audio file, with the voice of the instructor, which is streamed from the UIC server. Also, slides have hyperlinks to enhance the understanding of some concepts. An experimental class such as Microdevices and Micromachining Technology, is based on web pages that contains text, drawings, pictures links to audio file for explanations, and links to videos and interactive animations. Lecture materials are prepared using mainly Macromedia Dreamweaver, Microsoft PowerPoint, LaTeX, LaTeX2HTML, and Ansoft Maxwell. Students are accepted from worldwide locations. Finally, at UIC Professor David Naylor and Stephan Werges have developed the Interactive Electronics Laboratory (<http://www.mal.uic.edu/marble>), which allows remote access, at any time, to an actual laboratory equipped with real instruments and components. Users simply need to draw the circuit diagram (with a user friendly graphic interface) and, after a few seconds, a computer in the Interactive Electronics Laboratory creates the circuit, runs measurements according to the

specified input data, and immediately provides digital results. This facility is extremely beneficial for education purposes because students can quickly build up their circuits allowing more time for investigating the effect of variations of parameters and for making comparisons with circuit simulators to understand their limitations.