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Advanced Technology for Engineering Education

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July 1998

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Preface

This document contains the proceedings of the Workshop on Advanced Technology for Engineering Education, held at the Peninsula Graduate Engineering Center, Hampton, Virginia, February 24-25, 1998. The workshop was jointly sponsored by the University of Virginia's Center for Advanced Computational Technology and NASA. Workshop attendees came from NASA, other government agencies, industry and universities. The objectives of the workshop were to assess the status of advanced technologies for engineering education and to explore the possibility of forming a consortium of interested individuals/universities for curriculum reform and development using advanced technologies. The presentations covered novel delivery systems and several implementations of new technologies for engineering education.

Certain materials and products are identified in this publication in order to specify adequately the materials and products that were investigated in the research effort. In no case does such identification imply recommendation or endorsement of products by NASA, nor does it imply that the materials and products are the only ones or the best ones available for this purpose. In many cases equivalent materials and products are available and would probably produce equivalent results.

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Future University Environment and Scenario for Engineering Education

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Outline

Within the next few years a number of important technological developments will become so commonplace that they will be found in various buildings of university campuses, as well as at homes and businesses:

- increased processing power through new advanced processors and software techniques;
- integration of computers, television and telecommunications through digitization and compression techniques;
- immersive technologies for multidimensional scientific and engineering problems; and
- reduced costs and more flexible uses/applications of telecommunications through developments of high-capacity, high-bandwidth wireless and optical networks.

The implications of these developments for the university environment in general, and for engineering education and training in particular, are immense. The focus of this presentation is on future university environments and engineering education. The outline is given in Fig. 1. First, the relevant technologies that impact engineering education are briefly described; second, some of the characteristics of the emerging and future university environments are discussed; third, a proposed model is presented for engineering courses; and fourth, the objectives and format of the workshop are outlined.

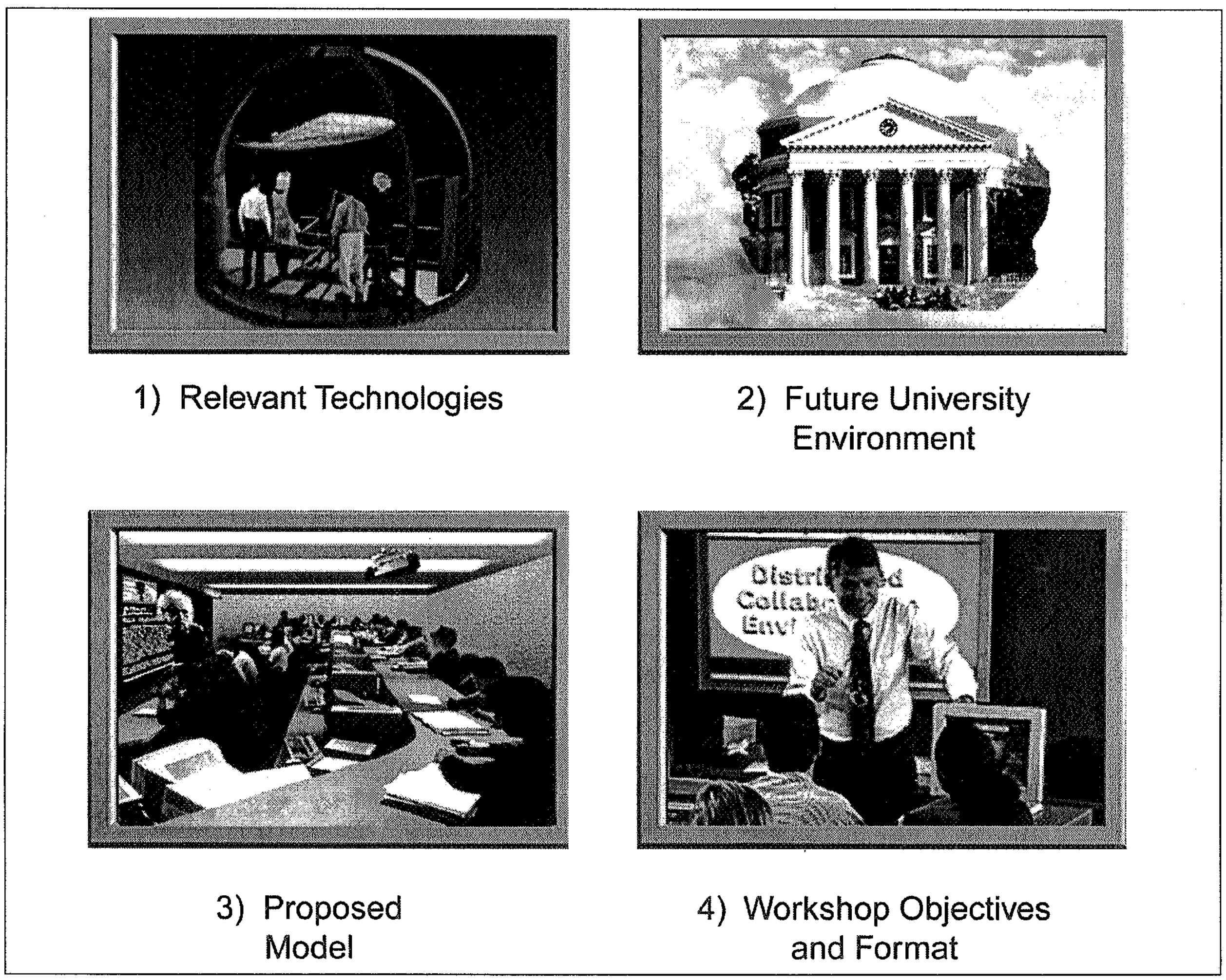


Figure 1

Relevant Technologies

The relevant technologies that can significantly impact university education can be grouped into four categories: information technology and infrastructure, collaboration technology, modeling and simulation technology, and instructional technology (Fig. 2). The synergistic combination of these technologies can dramatically increase the effectiveness of education. Learning can be independent of time and place, and available at all stages of a person's life. The learning context will be technologically rich. Learners will have access not only to a wide range of media, but also to a wide range of resources of education and training.

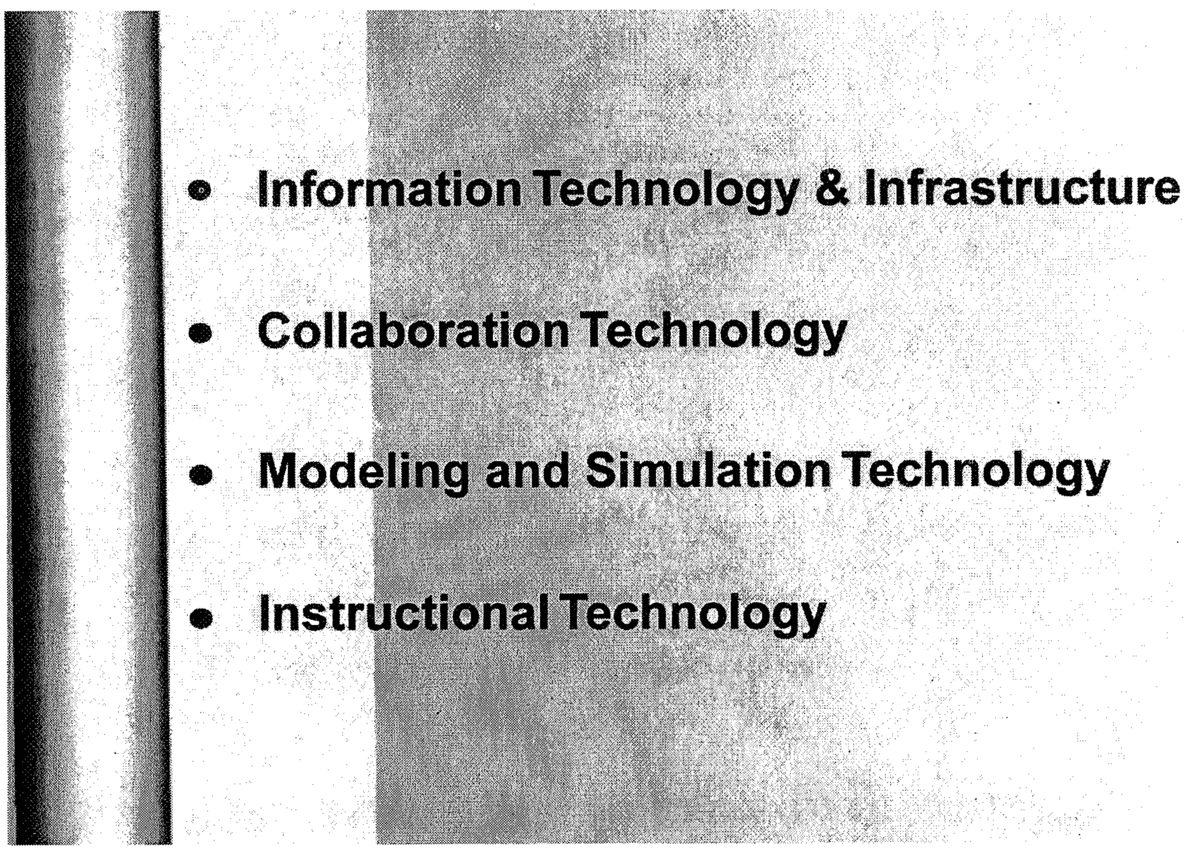


Figure 2

Ultrafast Computers, Powerful Microprocessors, Laptops and Wearable Computers

Information technology and infrastructure covers a broad spectrum of component technologies, including computing, networking, human-computer interface, digital libraries and intelligent agent technologies. Some of the component technologies are briefly described in the succeeding figures. Computing technology covers a broad spectrum of technologies (Fig. 3) ranging from the ultrafast computers such as the three teraflop machines of the Department of Energy to the powerful microprocessors and visual computers, with motion video instruction (MVI) facilities such as those based on the new Intel and alpha processors. This superset of desktop multimedia PCs is based on Windows NT. They will have motion-video instruction, especially suited for image processing, three-dimensional animations, motion video, and visual communications. By September 1999, the speed of the Intel and alpha processors will reach 600 and 1200 MHz, respectively.

Laptops are becoming powerful (e.g., 266 MHz laptops are now available), so are wearable voice-activated computers that are especially suited for virtual environment.

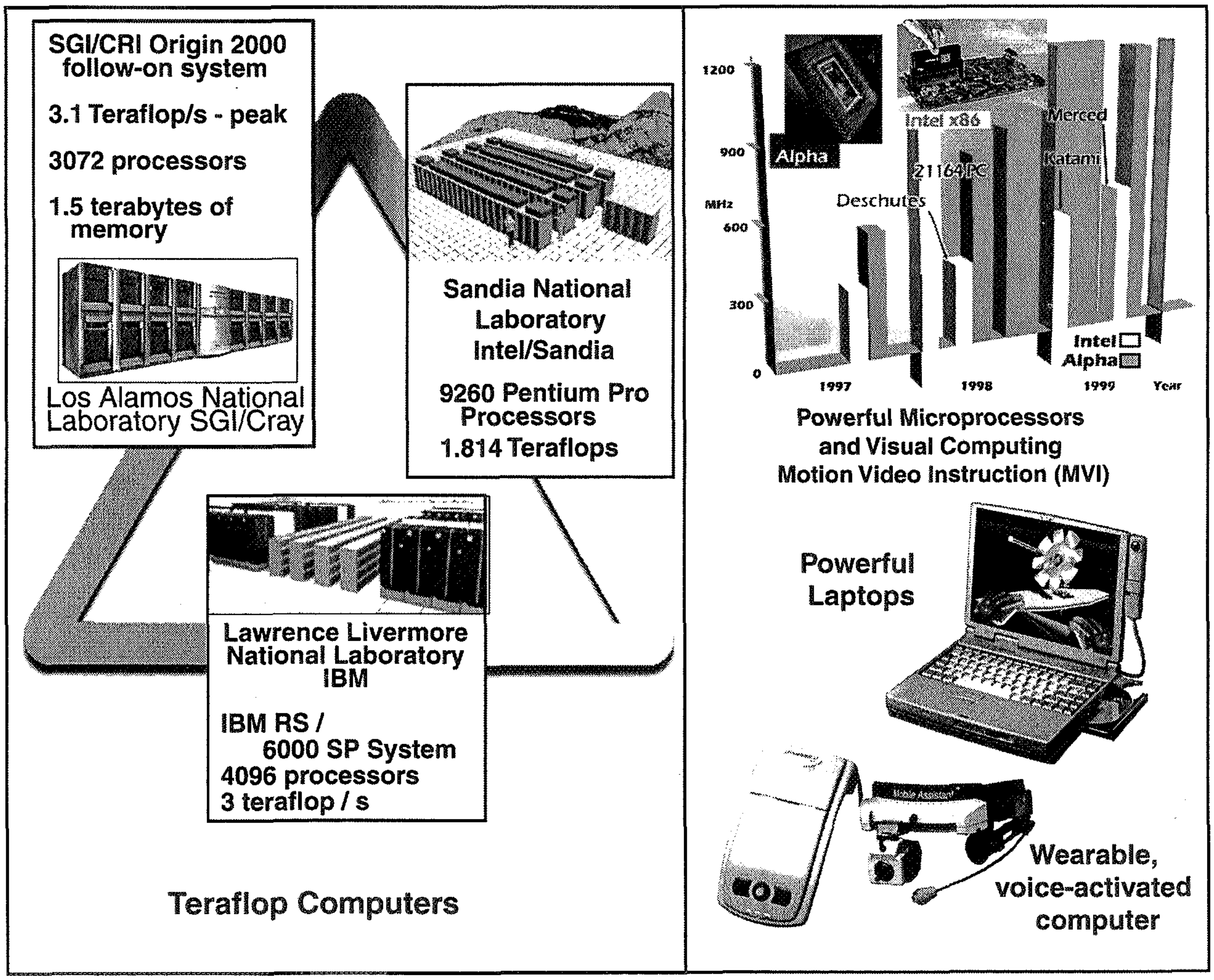


Figure 3

The Internet, Network Computers and Net PCs

The Internet has made a significant impact on the university environment as well as on businesses. Through the use of very sophisticated routers, bridges and switches, it has provided immediate access to information anytime, anywhere with minimal maintenance. It has cross-platform support. Although the Internet use is steadily increasing, the majority of its use is for research/ information (48%), and email communications (41%). The education/training use of the Internet is estimated to be 4% (Fig. 4).

Two new categories of computers have recently been developed in connection with the networks and the Internet: network computers and Net PCs. Network computers do not have local hard disks, do not allow local operations, and are particularly aimed at Java-type applications. Net PCs support small local hard disks, allow local operations, and aim at Windows-type applications (Fig. 4).

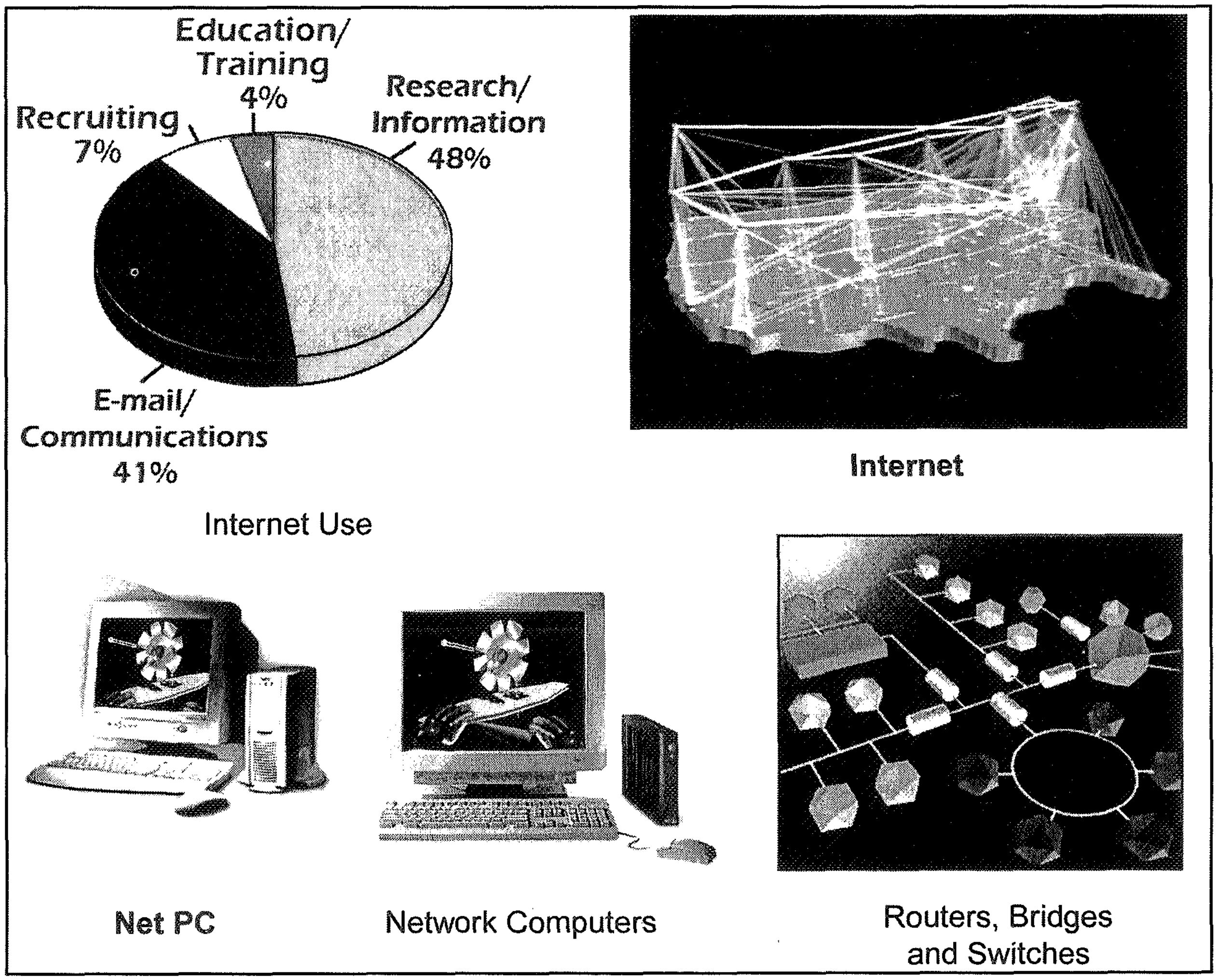


Figure 4

Internet Speed and Carrier Technology

The Internet speeds (data rates) provided by different carrier technologies are shown in Fig. 5. Current speeds of regular telephone modems can reach 56 Kbps (kilobits per second). ISDN (Integrated Services Digital Network) have speeds ranging from 64 to 128 Kbps for Basic Rate Interface (PRI). Digital satellite connections (e.g., DirecPC) can provide speeds of up to 400 Kbps. The speed of IDSL (ISDN Digital subscriber line) is 128 Kbps. The standard local area network, the Ethernet, has a speed of 10 Mbps. The speeds provided by the fast Ethernet and FDDI (Fiber Distributed Data Interface) is 100 Mbps. The speeds of the T-1, T-2 and T-3 networks are 1.544, 6.312 and 45 Mbps, respectively.

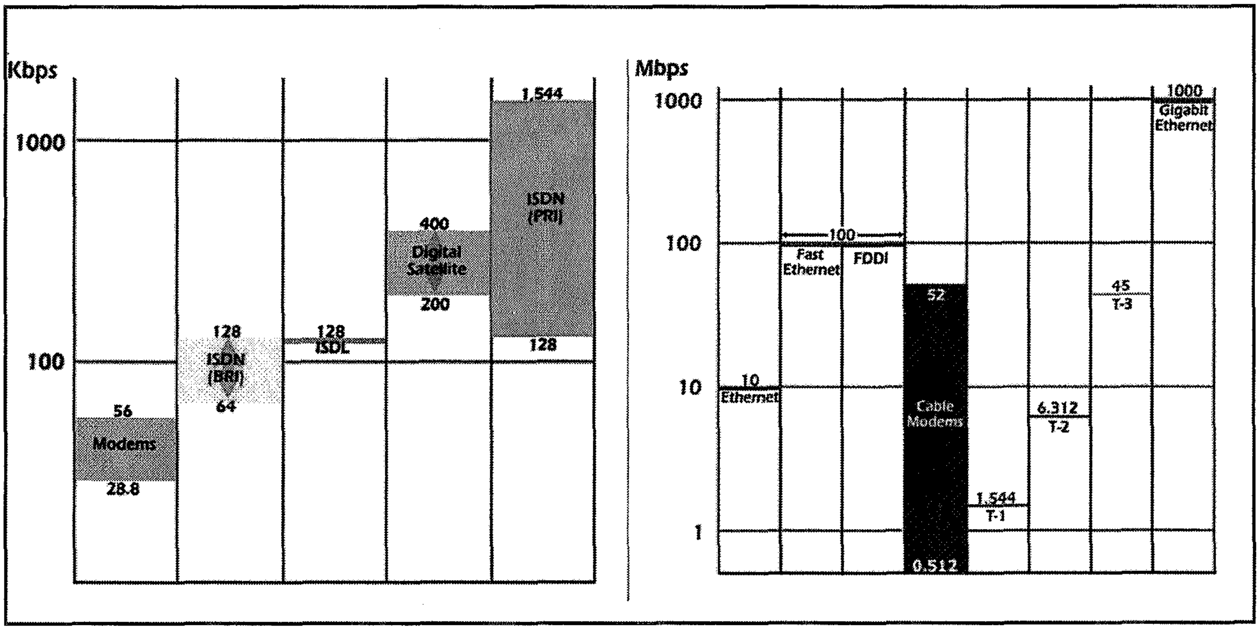


Figure 5

Future High Performance Networks

Future high-performance networks include Next-Generation Internet (NGI) and Internet 2 (Fig. 6). By leaping ahead with a new generation of network technologies, both networks significantly increase the capacity, cost and performance, and reduce the cost of communications. NGI is a multi-agency project sponsored by DARPA, NSF, DOE, NASA and NIST. It is expected to increase the transmission capacity to 10 terabits per second by the year 2005. As of March 1998 a consortium of 122 universities, 20 affiliated nonprofit organizations, 10 industrial partners and 17 corporate members supports Internet 2.

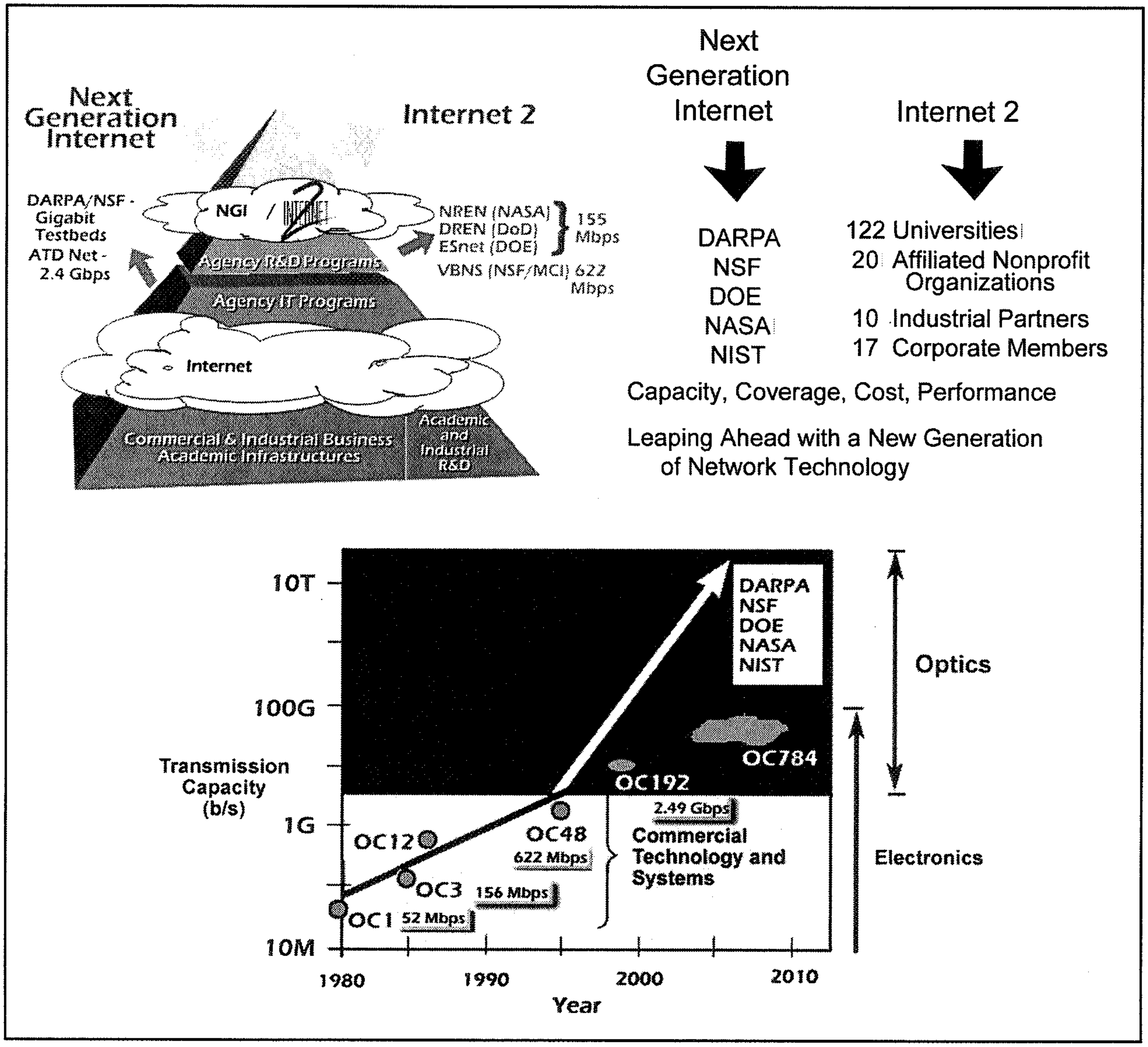


Figure 6

Visualization and Immersive Technologies

In the area of visualization technologies, multimedia, sonification and virtual reality facilities can have a significant impact on enhancing our understanding of the physical phenomena associated with large-scale numerical simulations (Fig. 7). Virtual reality facilities cover a broad spectrum ranging from those used on laptop and desktop computers to small group VR (such as the immersadesk and the immersive workbench) to the CAVE, Vision Dome and Reality Center. The Vision Dome and Reality Center provide an immersive three-dimensional virtual reality environment that gives users a wider field of view of the product model without head-mounted displays or stereo glasses.

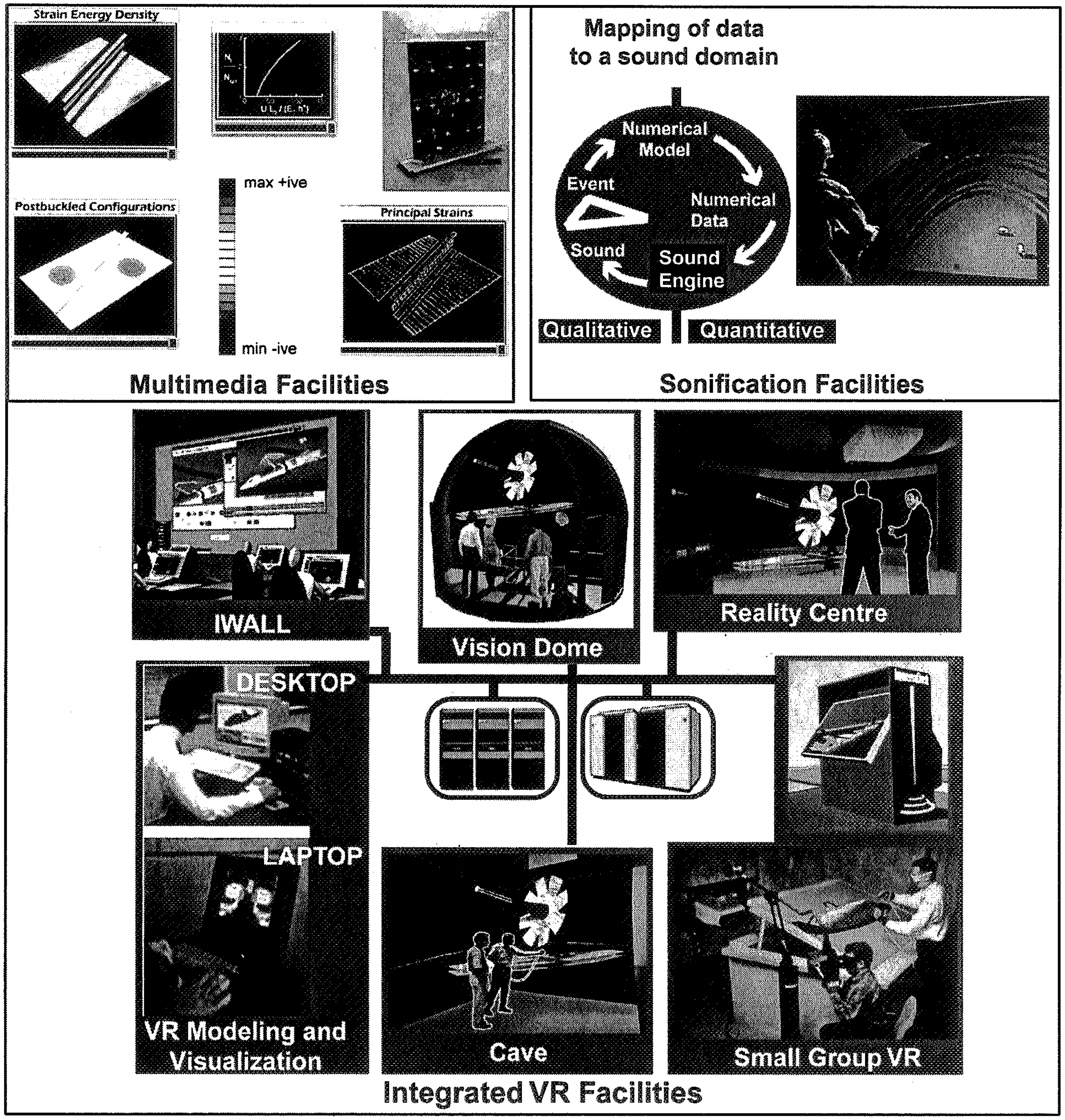


Figure 7

Advanced Human-Computer Interfaces

Current human-computer interfaces are based on WIMP (windows, icons, menus and pointing devices). Future HCI will use cognitive neuroscience to couple humans with computers and maximize the performance of both. Natural languages will provide effortless communication with the computer and the interfaces will be adaptive and reconfigurable.

Two categories of interfaces that can be used to identify different states of mental alertness are shown in Fig. 8. Neural interfaces, based on brain waves (e.g., alpha waves and mu waves); and biological interfaces using EMGs (electromyographic signals). The user wears a specially designed headband with electrodes that can detect electrical signals from the muscles when they pass through the skin. An amplifier is used to amplify the tiny signals from the muscles. An analog-to-digital converter is used to translate the voltage to the computer, and a digital signal processor is used to extract important features of the signal (reflecting the mental alertness of the user and the computer responds by selecting a suitable interface). An optical isolation device is used to avoid electric shock for the user.

Ultimately, it is desirable to have computers with thought-recognition - minds coupled to computers - a person thinks of a command and the computer immediately responds - a scheme analogous to voice recognition in use today.

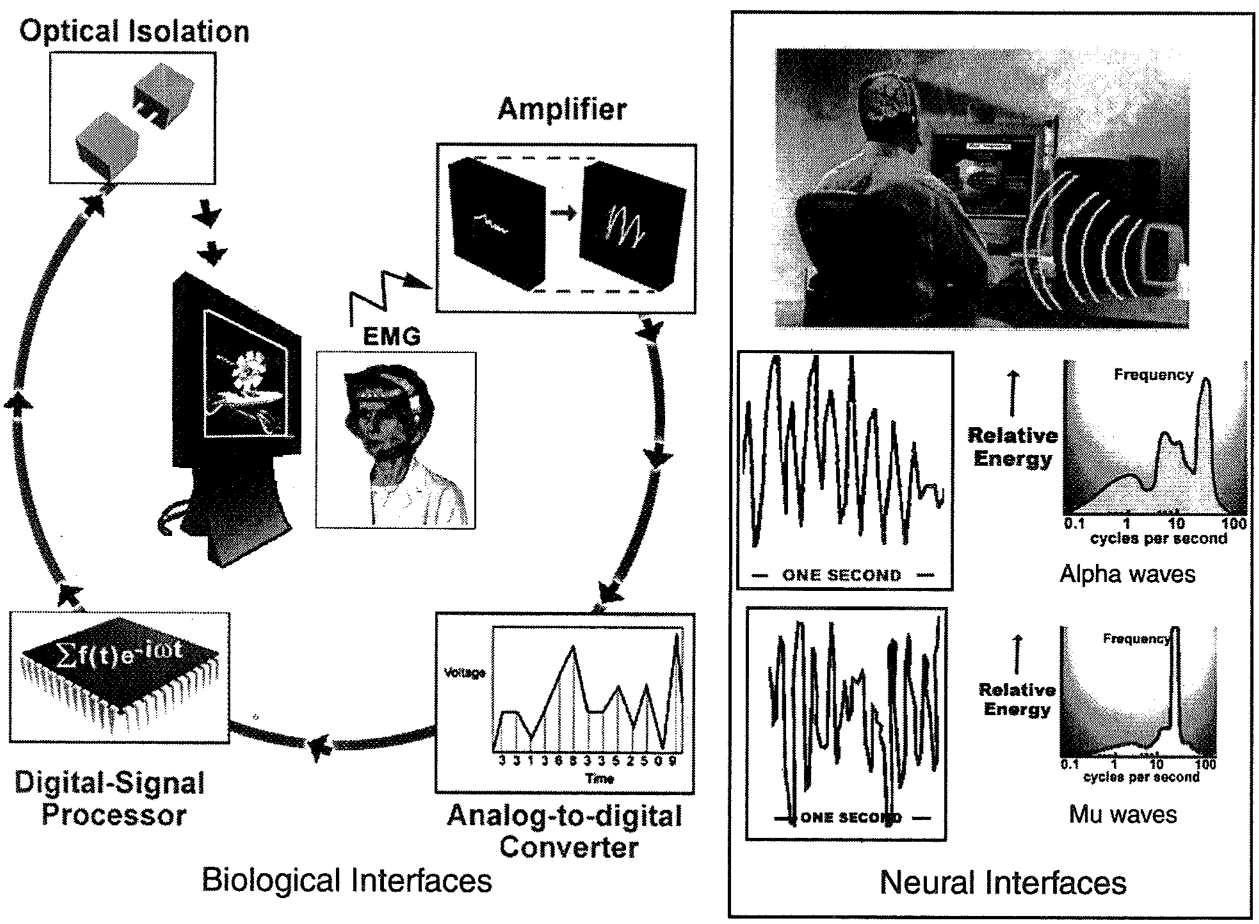


Figure 8

Digital Libraries and Intelligent Agents

Two of the component technologies of information technology are digital libraries and intelligent agents (Fig. 9). Digital libraries, which basically store information in electronic format, manipulate large collections of information effectively and provide vastly improved access to this information over the network. Several universities, industries and professional societies have established digital libraries.

In the networked environment, an enormous amount of information is available from a wide variety of sources. Intelligent software agents are an emerging technology that can help the Internet user find, filter and prioritize information, as well as customize views of information (including text, equations and images) and automate work.

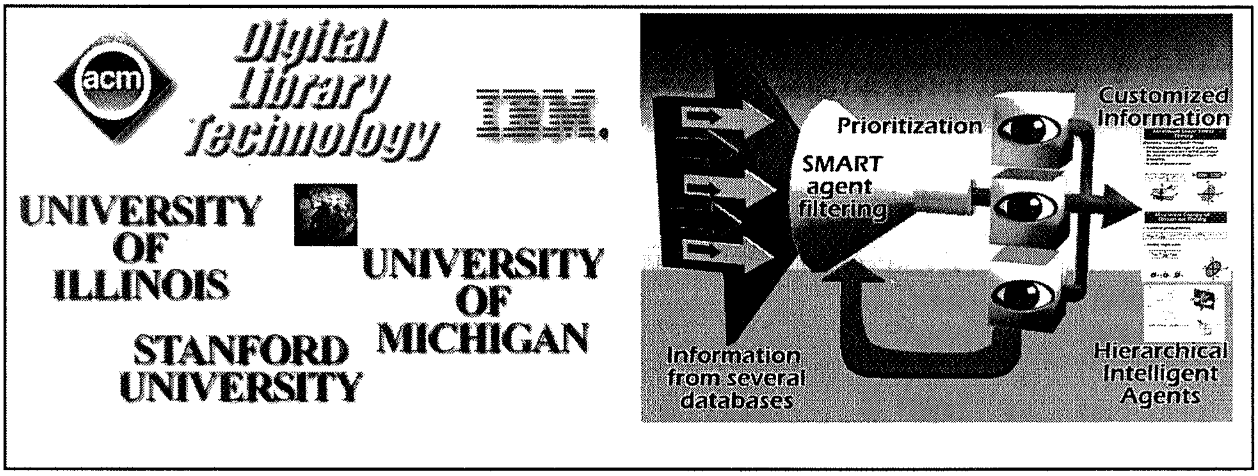


Figure 9

Distributed Heterogeneous Virtual Reality Facilities

The next category of technologies is the collaborative technologies. These technologies allow geographically dispersed teams to work together. An example of these technologies is the distributed heterogeneous virtual reality facilities that provide a multi-perspective view of the product model (Fig. 10).

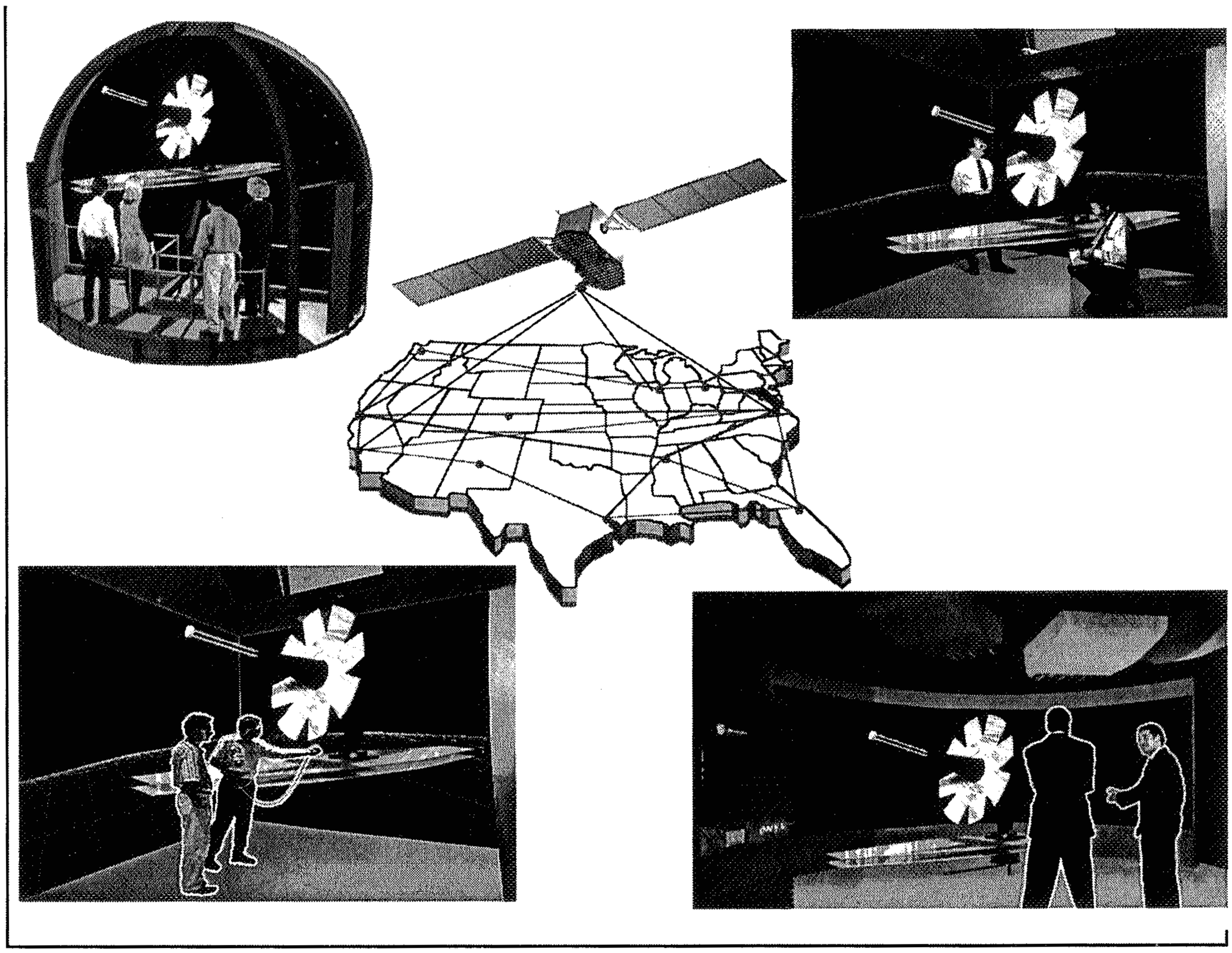


Figure 10

Knowledge and Distributed Intelligence

The National Science Foundation's Knowledge and Distributed Intelligence (KDI) Program aims at a) facilitating the collaboration and interactivity across space, time, disciplines and scientific cultures; b) helping scientific and engineering teams in modeling and representing more complex and cross-disciplinary scientific data from new sources and at enormously varying scales; and c) transforming this information into knowledge by combining, classifying and analyzing it in new ways.

KDI has three foci, namely: Knowledge Networking (KN); Learning and Intelligent Systems (LIS); and New Challenges in Computation (NCC) (Fig. 11). KN focuses on the integration of knowledge from different sources and domains across space and time. LIS is a multidisciplinary activity that spans neuroscience, cognitive science, computer science/AI, and software design.

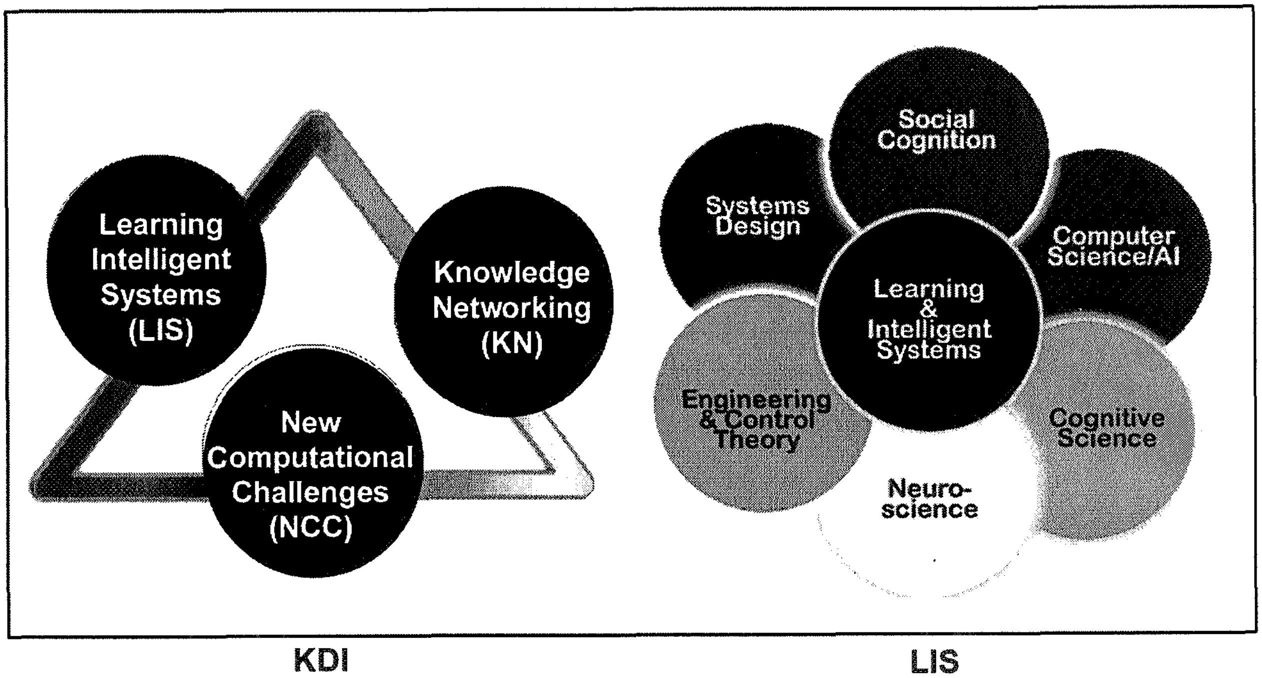


Figure 11

Immersive Telepresence

Immersive telepresence refers to the virtual collocation of diverse teams, where distributed meeting takes place at specially designed conference rooms located at remote sites. Participants are able to interact fully, even exchanging objects and walking around each other (eventually with a full-scale system), in three dimensions. No special glasses, wands or gloves are required (Fig. 12).

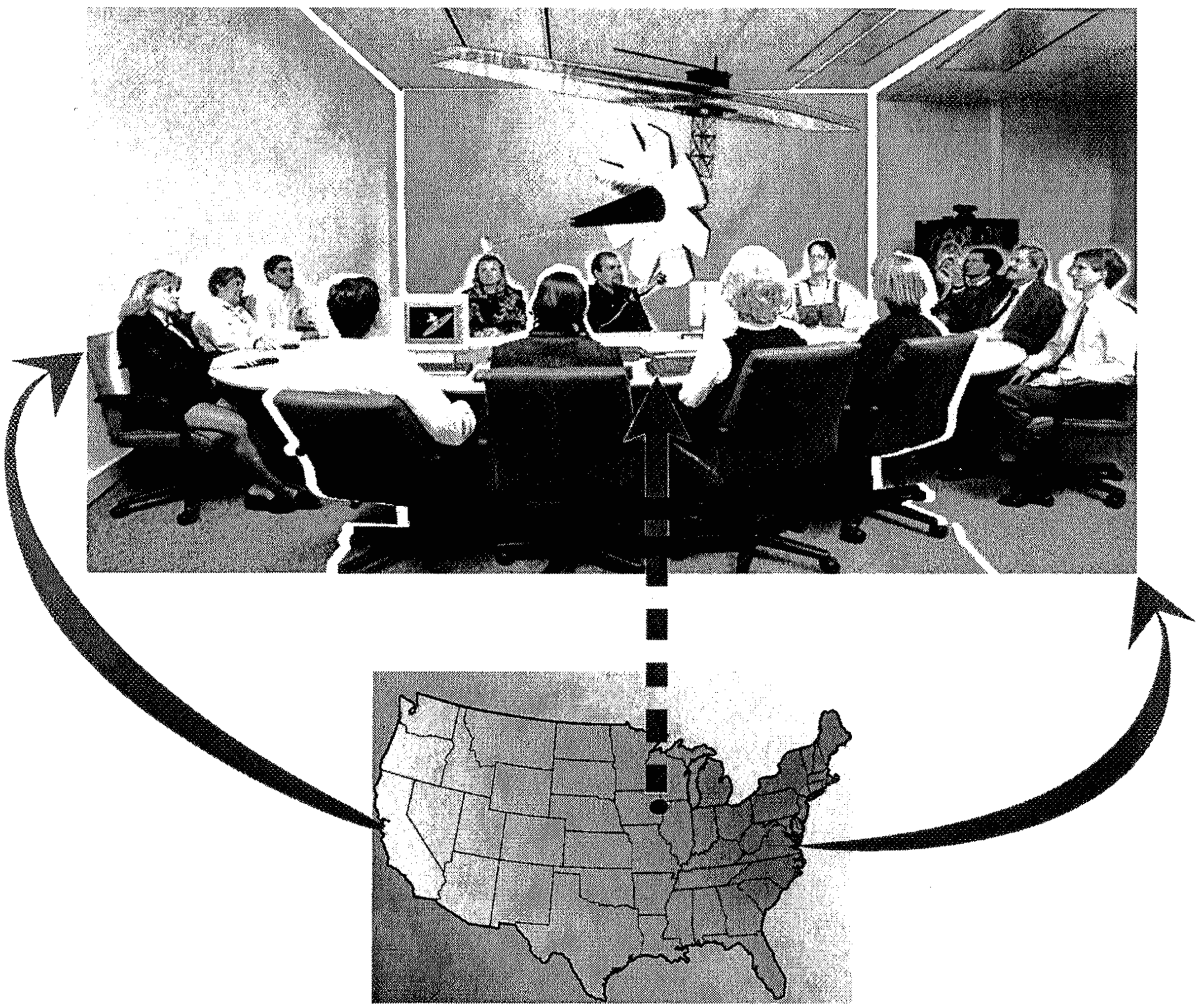


Figure 12

Modeling and Simulation Technology

Modeling and simulation technology covers a broad spectrum of component technologies and simulation tools, including traditional deterministic and nondeterministic disciplinary and multidisciplinary methods. They also have tools for life-cycle simulations, including virtual manufacturing and prototyping; maintenance; operations; and training (Fig. 13). Less developed are the computational models of learning, understanding and instruction.

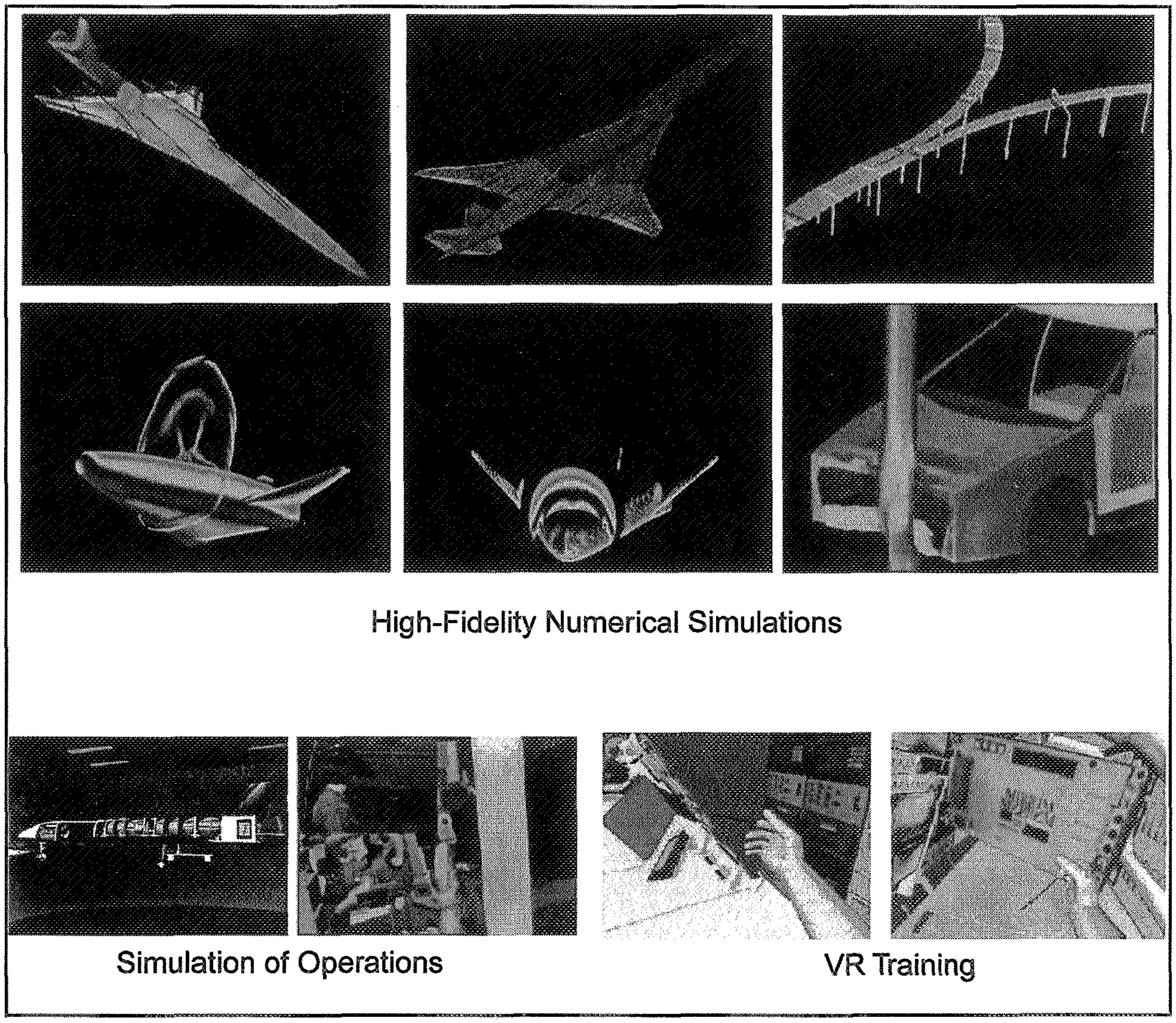


Figure 13

Instructional Technology

Instructional technology covers instructional design, learning environment, authoring tools, and evaluation tools. Several authoring tools are available on various platforms, as well as on the World Wide Web. Examples are provided by Macromedia authoring tools and the online course-building environment Webct of the University of British Columbia (Fig. 14).

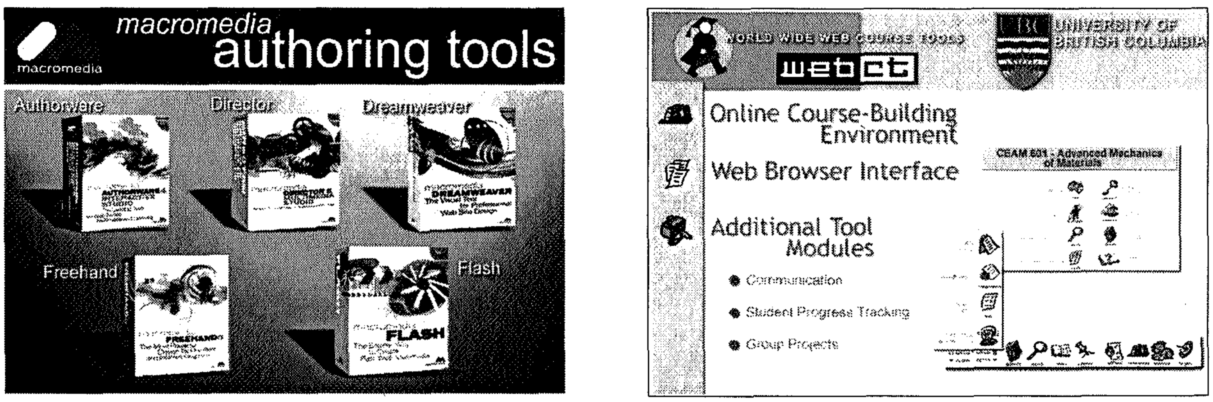


Figure 14

Future University Environment

The second part of the presentation focuses on the future university environment as impacted by the relevant technologies. The topics covered are future expectations from universities, role of faculty, curriculum reform and delivery system, instructional models and learning objectives, and finally, emerging and innovative learning and instructional models (Fig. 15).

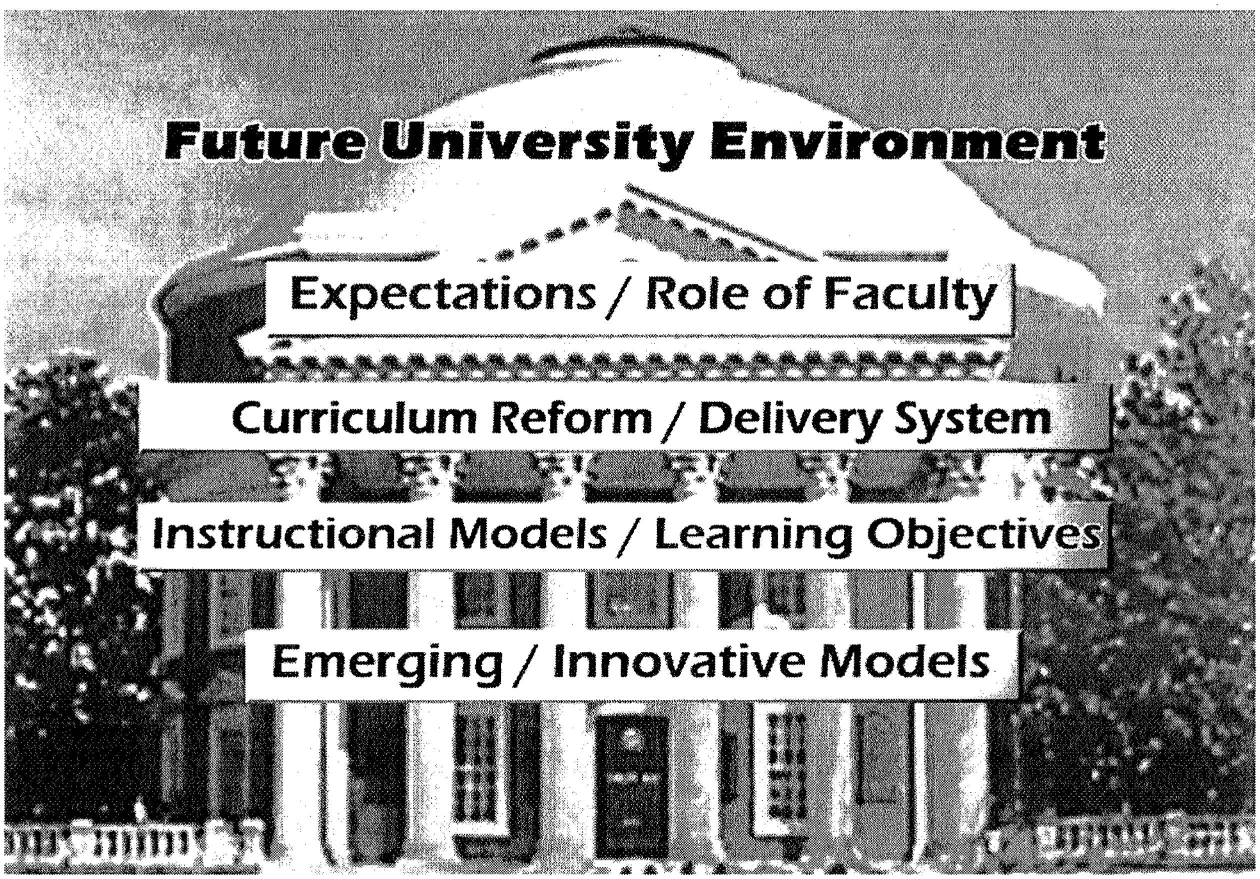


Figure 15

Future Teaching Function of the University

Although information technology, networking and digital media may impact the future of university education, the changes in the workplace and political processes are the forces exerting the greatest pressures on universities to change.

The teaching function of the university will be reshaped by new expectations from students concerned about the return on their investment in education - from business leaders seeking graduates with practical competence and from politicians who want more efficient and effective education for the state's subsidies - and by new technologies and competition from private firms.

Faculty has traditionally been information transmitters. Their role in the future will change to that of course managers and coaches who inspire and motivate students, and not merely transmit information (Fig. 16).

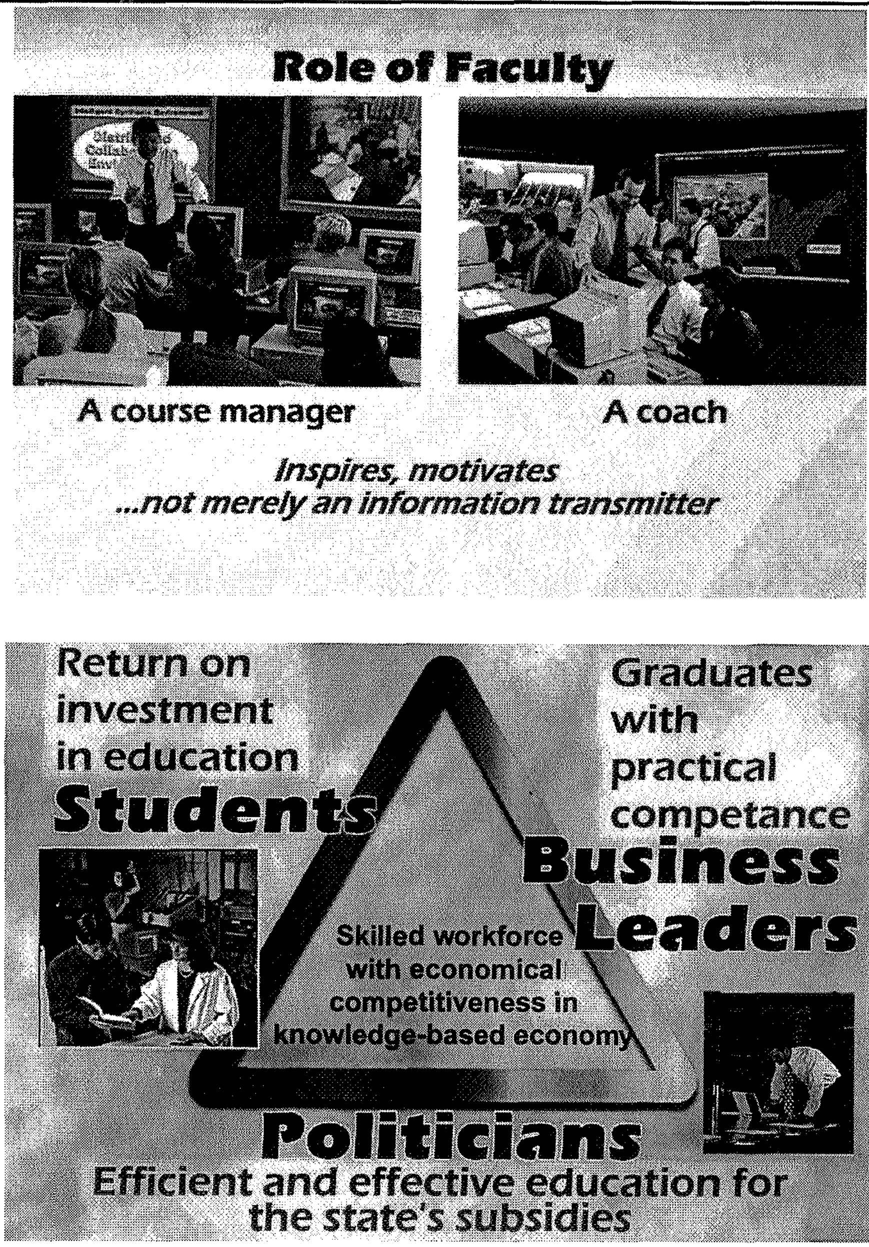


Figure 16

Forces Driving Change in Curriculum and Delivery System

Educational institutions are influenced by societal events constantly occurring around them. There are four categories of forces that are driving curriculum changes and delivery systems, namely (Fig. 17):

- Developments in the workplace:
  - The growth of knowledge in any field is rapidly outstripping any individual's ability to remain current. Knowing how to access information, rather than memorizing information, is central to coping with this rapid change.
  - Learners need frequent short-term updating as required skills change.
  - The increasing number of part-time workers requires a more flexible delivery system.

- Student demographics:
  - Trends show increasing numbers of older students.
  - Growing numbers of students are working part-time while enrolled in full-time programs. Again, they need a flexible delivery system.

- Economic pressures and financial constraints:
  - Operating costs continue to increase, while funding decreases.
  - Increased enrollment and lack of funding for classroom expansion.
  - Faculty number is not likely to increase. To get them to work harder will not produce greater efficiency.

- Competition:
  - Private for-profit businesses are offering short, inexpensive market-specific training programs. The training directly competes with traditional college programs.
  - On-line courses and training programs on the Internet are increasing.

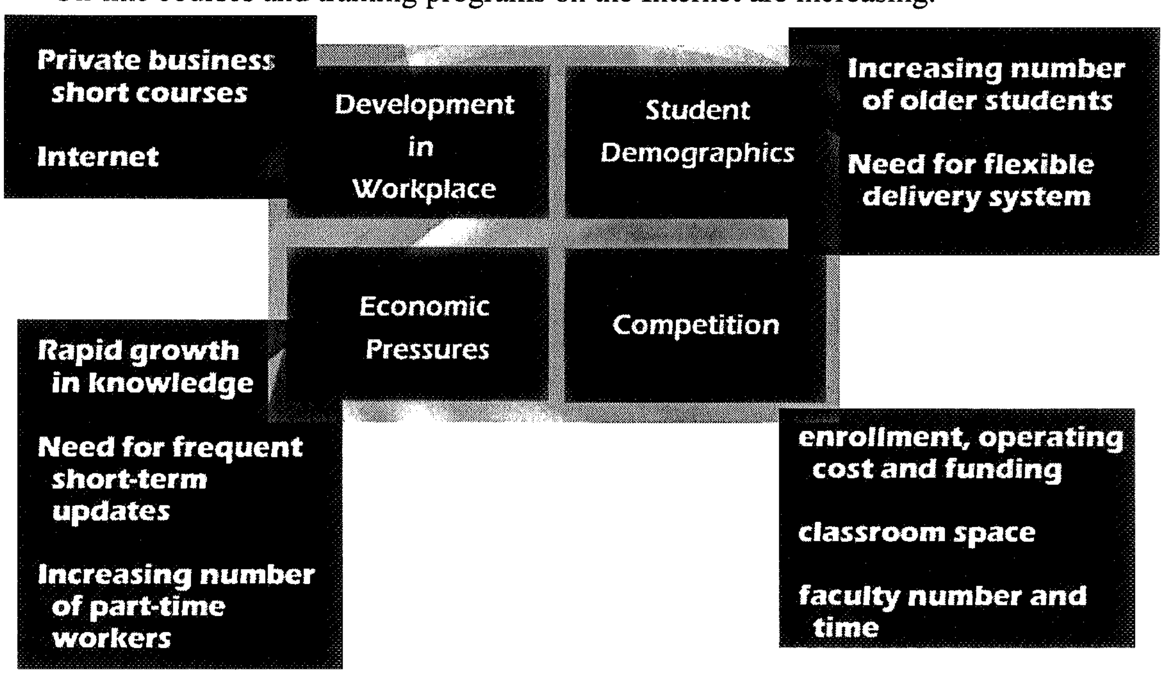


Figure 17

Curriculum Reform

Current undergraduate and graduate programs and delivery systems are not likely to meet the needs of the next century. The focus of the teaching mission of the university should be on the quests for meaning and relevance. The following changes should be made in the curriculum (Fig. 18).

- Emphasizing the distinction between knowledge and information - knowing how and knowing about.
- Providing flexible curricula - offering broader perspectives in dealing with complexity and uncertainty.
- Alignment of graduate educational offerings with the needs and interests of working professionals (special emphasis on certifying competence in selected areas).
- Transforming sequential classroom curriculum to nonlinear hyper-learning environment with flexible delivery system. In nonlinear instruction the learner selects his/her path to achieve the learning goal. Branching programs with remedial material are provided for self-instruction.

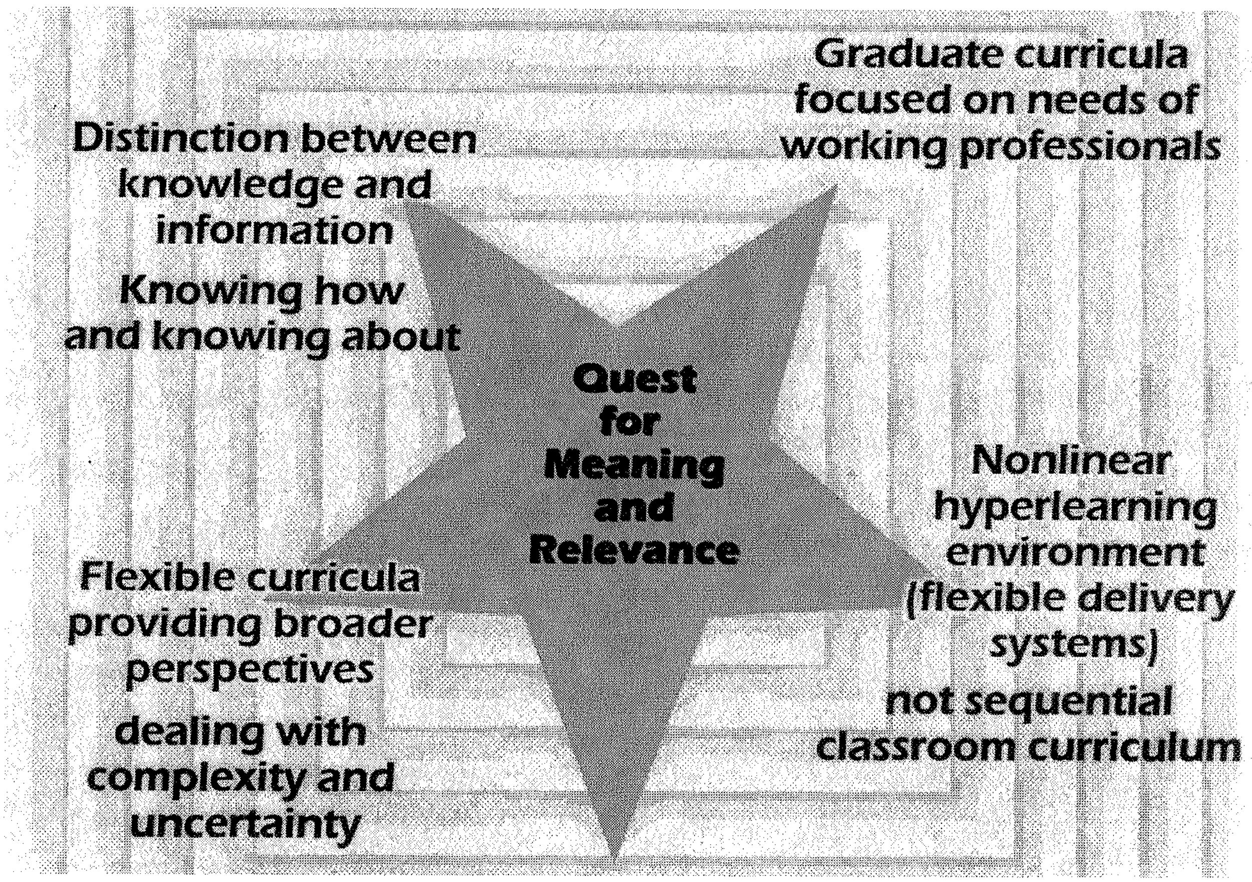


Figure 18

Electronic Learning Environment

The electronic learning environment is one of several forms of the educational environment. The range of possibilities for the electronic environment generated by varying displacement in time and place is shown in Fig. 19.

The traditional electronic classroom corresponds to the "same time, same place" model. One may argue that it is the most effective environment for education and communication because the instructor and learners have all mentally and physically committed themselves to a common window in time and space. The "different time, same place" model corresponds to electronic laboratories, which are useful, when the lab resources are limited. Synchronous (real time) distance learning is associated with the "same time, different place" model. The learners can be distributed across the country, or around the world, but they must all tune in to the class at the same time. This model is not new. Instructional television has been used for some time. The richness of distance learning has increased dramatically over time to include two-way and multi-way videos so that instructors and learners at different locations can see each other.

Finally, the "different time, different place" model corresponds to a very versatile asynchronous distributed learning environment. It provides facilities for delivering instruction any time and anywhere including on-line courses, virtual classrooms, individualized and computer-assisted instruction, and intelligent tutoring systems.

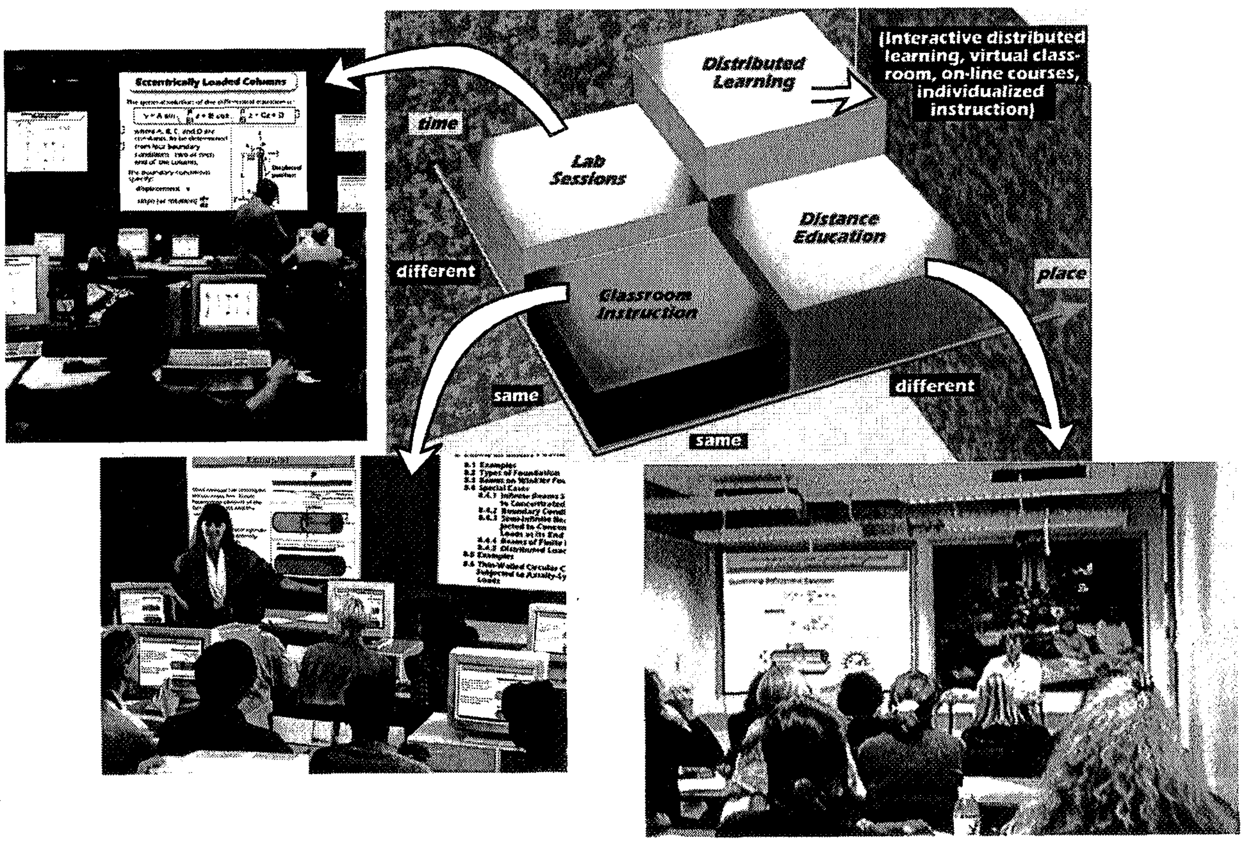


Figure 19

Learning Objectives, Instructional Models and Technologies

The desired outcome of learning can range from information transfer to skill and knowledge acquisition to the more ambitious goal of development of critical thinking and creativity skills. The instructional model and method used for accomplishing these goals vary from instructor-centered, learner-centered to learning-team centered. The technologies employed in the three cases are distribution, interactive and collaborative technologies, respectively (Fig. 20).

Figure 20

Emerging and Innovative Models

A number of innovative learning models are in use today, including on-line courses, virtual classrooms and virtual universities which provide distributed networked learning environments with custom self-instructional courses, flexible tutorial support and control over both the place and time of learning (Fig. 21). These new models may be viewed as attempts to reinventing the university. The level of sophistication of the facilities used in these models is rapidly increasing.

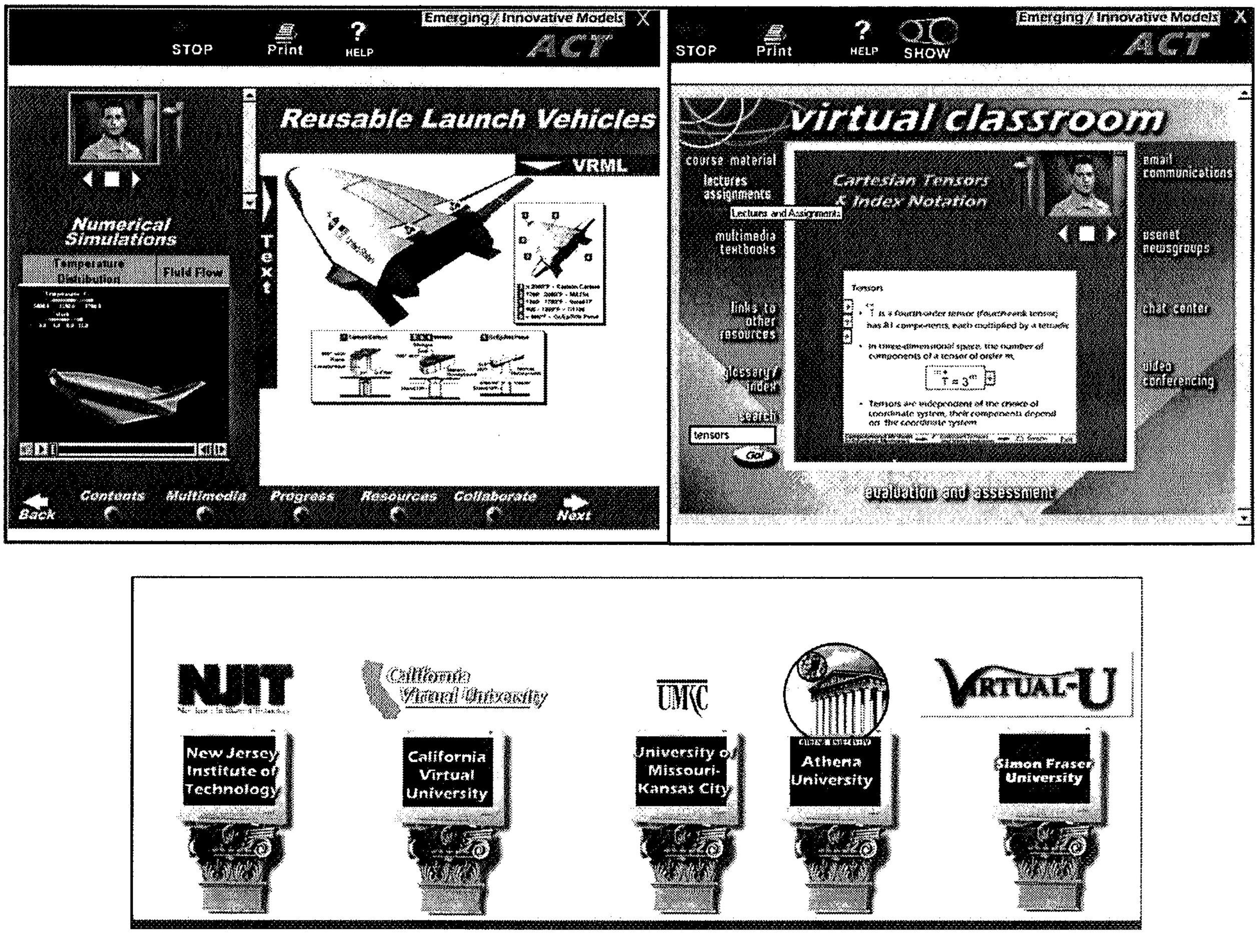
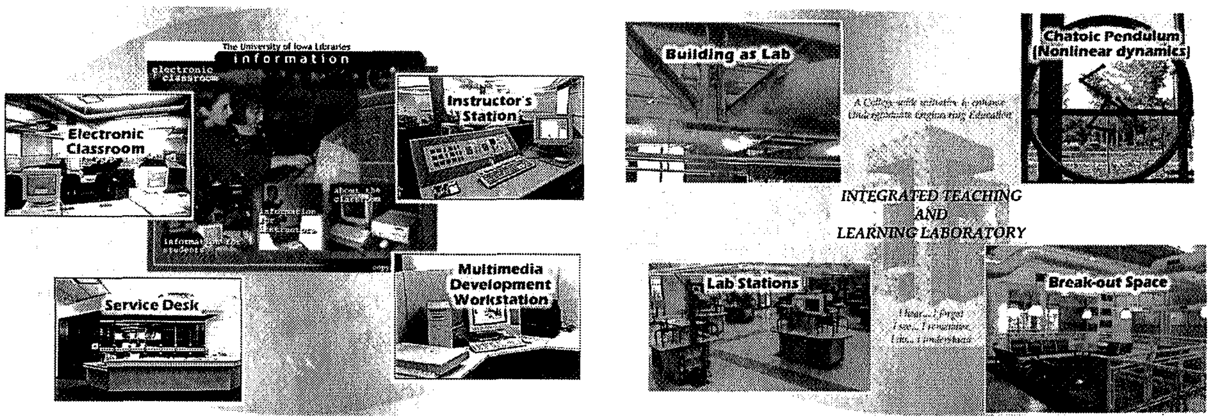


Figure 21

Examples of Elaborate New Learning Facilities

Some universities have invested in elaborate learning facilities. Two examples are shown in Fig. 22. The first example is the 1900 sq. ft networked electronic classroom facility of the University of Iowa. The second example is the Integrated Teaching and Learning (ITL) Laboratory of the University of Colorado at Boulder. The ITL lab is used as a learning tool. Students can monitor in real time the forces on the structural members. The building has sixteen LabStations, and a breakout space for instructor/student discussions. A chaotic pendulum, which is part of an art exhibit, is used to demonstrate nonlinear dynamic behavior.



University of Iowa **University of Colorado - Boulder**

Figure 22

Proposed Model for Engineering Courses

The three major components of the proposed model for engineering courses are shown in Fig. 23. These are:

- Reducing the lecture time to thirty minutes and focusing the lecture on broad overview of the topic and its diverse applications, and then ending the lecture with penetrating, what-if questions to help the students in developing critical thinking skills. Elaborate visualization and multimedia facilities are used in the lecture. Detailed derivation of equations and other mundane instructional tasks are relegated to computer laboratory sessions.
- Interactive/collaborative sessions are used to augment the classroom instruction.
- Knowledge-based learning-group management and evaluation tools are used to assess the comprehension of the learners and monitor their progress.

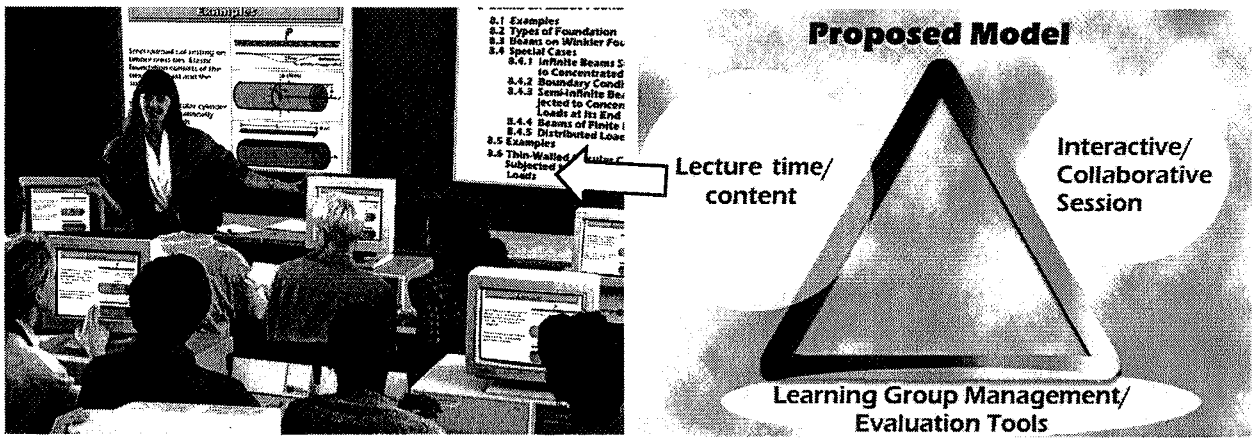


Figure 23

Interactive/Collaborative Sessions

The interactive/collaborative sessions are used for: a) self-paced instruction of the detailed derivation of equations and other routine instructional tasks, which are not covered in the lecture; b) understanding of physical phenomena using advanced visualization (e.g., animation), multimedia and immersive virtual reality facilities; c) virtual experiments (computer-simulation of physical experiments); d) skill-acquisition - virtual collocation of the learners in the shop floors of industry, and e) collaborative design projects through immersive telepresence, with geographically-distributed participants and instructors (Fig. 24).

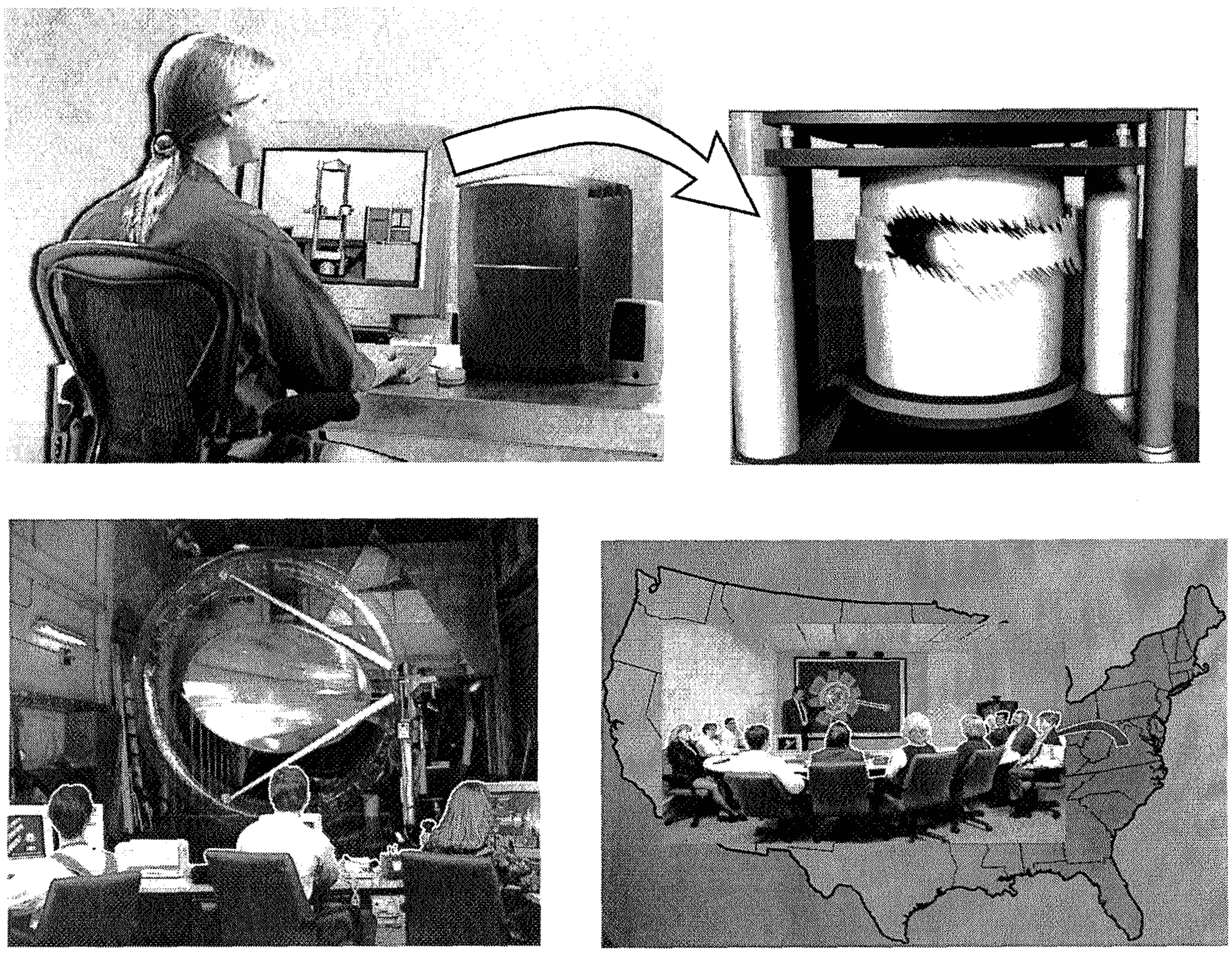


Figure 24

Evaluation Tools

Intelligent evaluation tools are used to relieve the faculty from the mundane tasks of testing and grading. Face recognition facilities (such as FaceIt software from Visionics, New Jersey) can be used to check the identity of the learner before the test is conducted (see Fig. 25). The learner is required to pass a test for every topic of the course before taking the final examination.

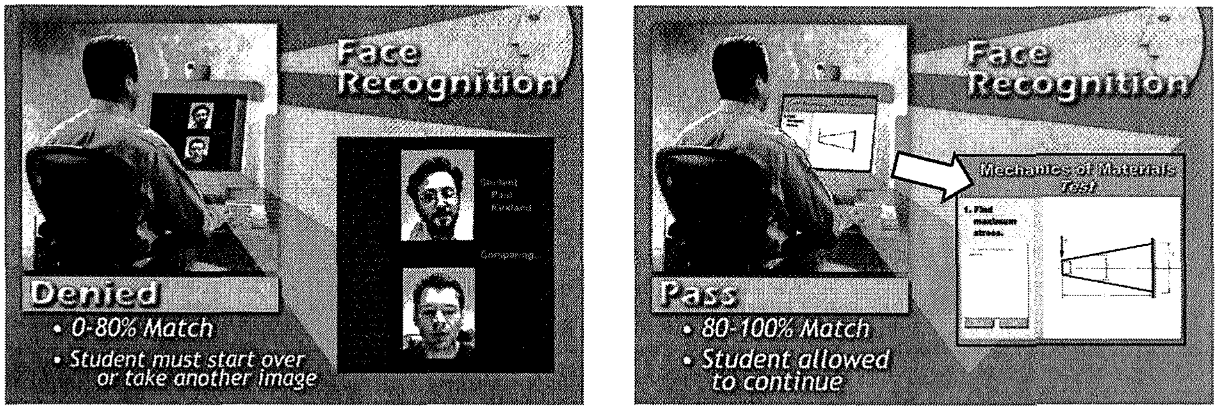


Figure 25

Objectives and Format of the Workshop

The objectives of the workshop are to (Fig. 26):

- assess the status of advanced technologies for engineering education; and
- explore the possibility of forming a consortium of interested individuals/universities for curriculum reform and development using advanced technologies.

The consortium can be used for evaluating multimedia and other advanced instructional facilities for engineering education, as well as serve as a mechanism for sharing these facilities, thereby significantly enhancing the effectiveness of engineering education at the institutions of the participants.

Objectives

Assess status of advanced technologies for engineering education and training

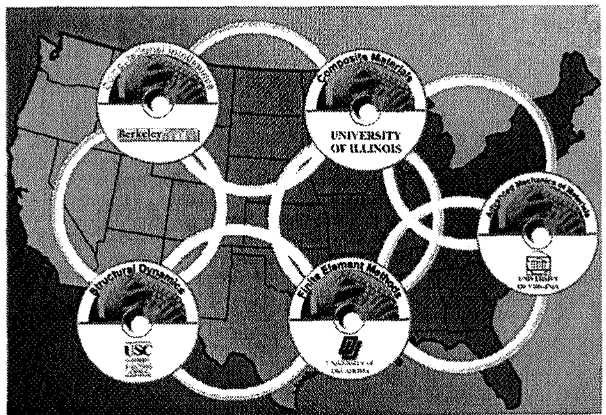
Explore the possibility of forming a consortium of interested individuals/ universities for curriculum reform and development using advanced technologies

Format

22 presentations, 8 sessions

Proceedings

NASA CP



Consortium

Figure 26

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30 P.

Some Thoughts on Multimedia Instructions for Engineering

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Some Thoughts on Multimedia Instructions for Engineering

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This presentation is a condensed version of material in: J. M. Mendel, "Multimedia Instruction for Engineering Backbreaker-Concepts," (preprint) Feb. 1998, Sections I-V, IX-XI.

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Some Thoughts on Multimedia Instruction for Engineering

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Multimedia

Multimedia, as has been frequently noted, means different things to different people. We shall adopt the **USC Integrated Media System Center's** view that *multimedia is the creation and packaging of information and the dissemination and distribution of information through end-user interactive applications*. It is the fusion of video, animation, simulation, graphics, data, text, and audio into an interactive application.

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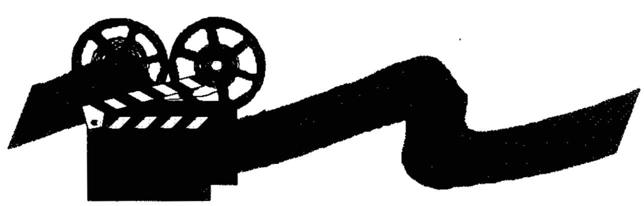
Multimedia

- **Means different things to different people**
- **IMSC's view:**
  - **Multimedia is the creation and packaging of information and the dissemination and distribution of information through end-user interactive applications**
  - **Fusion of video, animation, simulation, graphics, data, text, and audio into an interactive application**



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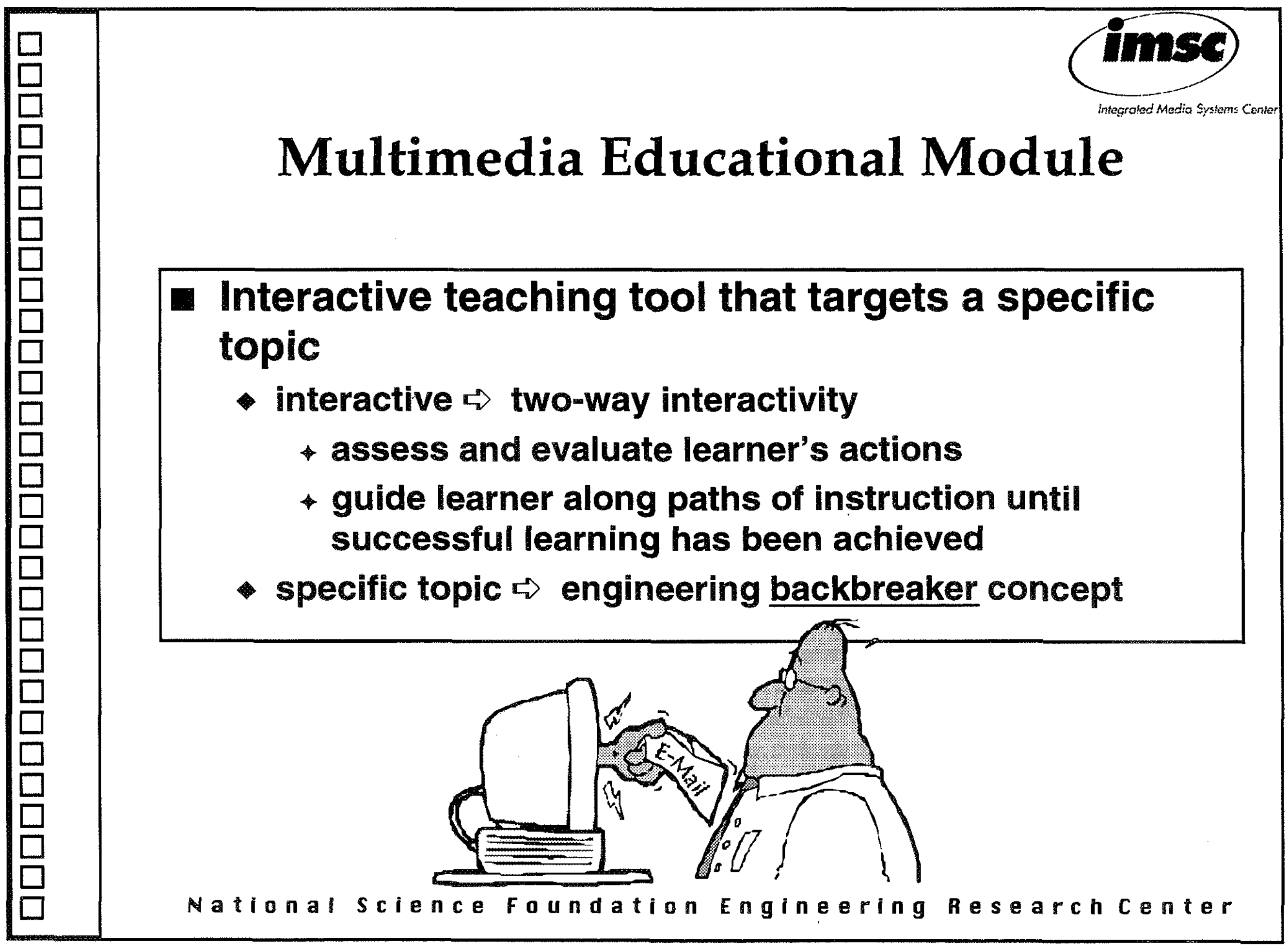
Multimedia Educational Module

A multimedia educational module (referred to in the sequel as a *module* or *interactive module*) is an *interactive* teaching tool that targets a specific topic. In this paper, I advocate that modules should be created for engineering "backbreaker-concepts," because doing so can lead to higher student performance and retention.

By "interactive," I mean *two-way* interactivity with a device, such as a TV or personal computer. A person should be able to interact with the device and it should be able to interact with the person. One-way interactivity, such as turning pages in a computerized text, is not emblematic of the type of educational interactivity we hope for in a multimedia module. The device must be able to assess and evaluate the learner's actions, and guide the learner along paths of instruction, until successful learning has been achieved. Although such two-way interactivity may not be completely available now, it surely must become available if modules are to live up to their full potential.



Backbreaker Concept: 1

A backbreaker concept, which occurs in a specific course, is one that students find very difficult, one that is important to the rest of the course, and one that is also needed for other courses. Some examples of backbreaker concepts are: convolution (in a first course on linear systems) and stochastic convergence modalities (in a first course on probability).

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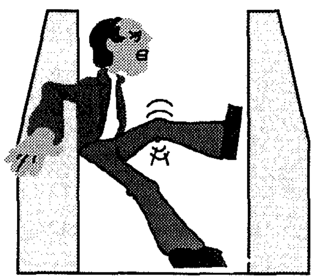
Backbreaker-Concept: 1

- Occurs in a specific course
- Students find it very difficult
- Important to rest of course
- Also needed for other courses
  - e.g., convolution, stochastic convergence modalities, divergence and curl, ...



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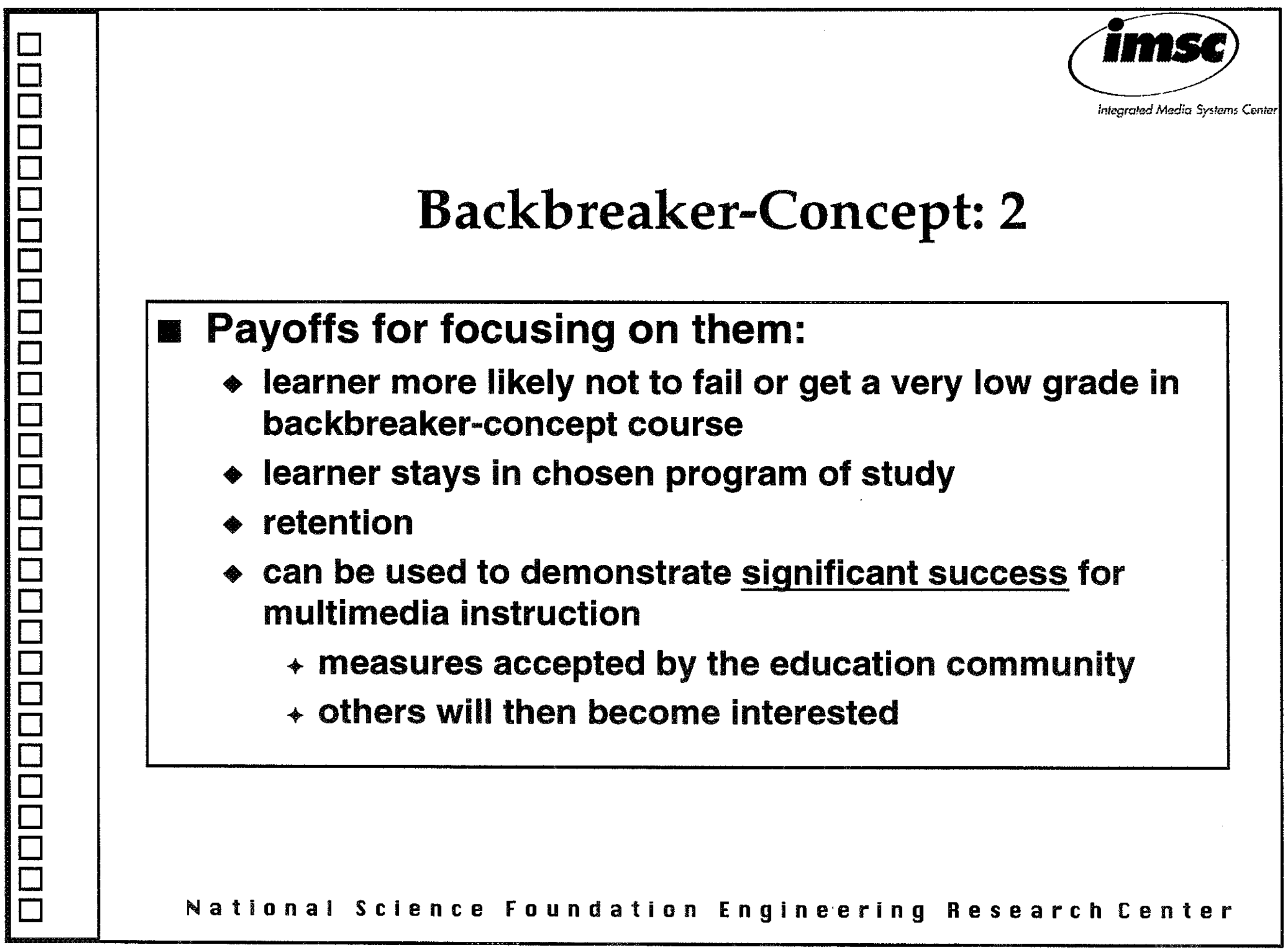
Backbreaker Concept: 2

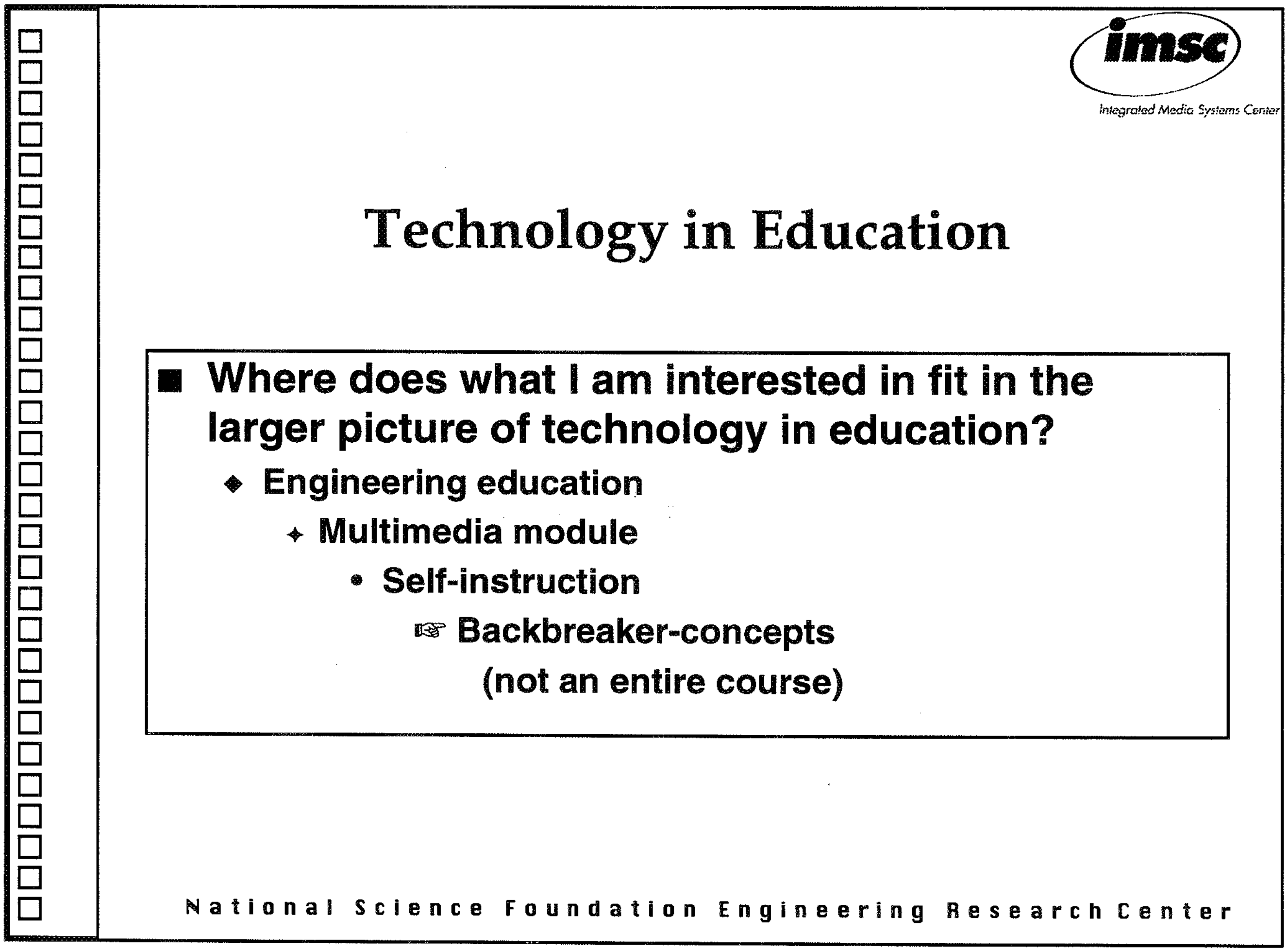
There can be big payoffs to the learner and to the university for faculty developing backbreaker concept modules. By mastering a backbreaker concept, the learner is more likely not to fail or get a very low grade in the backbreaker-concept course, and this, of course, will help let them stay in their chosen program of study. Their *retention* is of great importance to a school of engineering.

For multimedia instruction to become of interest to a broad group of engineering educators, it is incumbent upon the developers of the early educational modules to have results where it is obvious to everyone that a substantial improvement in education (measured in terms that are important to and accepted by the education industry) has occurred; so, choosing the subject topic is crucial, and evaluating the importance of it ahead of time, in relation to accepted educational objectives is vital. It should be possible to do this for backbreaker concepts.



Technology in Education

My focus is on developing a self-instructional multimedia module for an engineering backbreaker concept, rather than on developing an entire course into a multimedia product. This does not mean that I am against doing the latter. It means that, at present, I can strongly justify doing the former, and therefore prefer to focus on it.



Main Purpose of Work

This article is directed at the many engineering educators who, like myself, have had no earlier formal training in instruction theory. When "stand and deliver" was the modus operandi for us, formal training in instruction (not instruction theory) was provided by our mentors - our professors. For the most part, this served us well. Multimedia instruction, however, breaks the mold of "stand and deliver," so it is now important for engineering educators who are interested in developing multimedia modules to learn appropriate instructional techniques. Such techniques have been developed, tried, and tested in the education (as distinct from engineering education) field for many years, so they do not have to be reinvented by engineering educators. Instead, these techniques need to be understood and questioned as to their suitability for engineering multimedia module development. This paper then is written in the spirit of interdisciplinarity between "Engineering Education" and "Education."

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Main Purpose of Work

- **Encourage engineering educators to do critical thinking about multimedia instruction**
  - **Most engineering educators have no formal training in instruction theory**
  - **Multimedia module breaks mold of "stand and deliver" instruction**
  - **Module developers need to become familiar with educational instruction theories**
  - **Interdisciplinarity between "Engineering Education" and "Education"**

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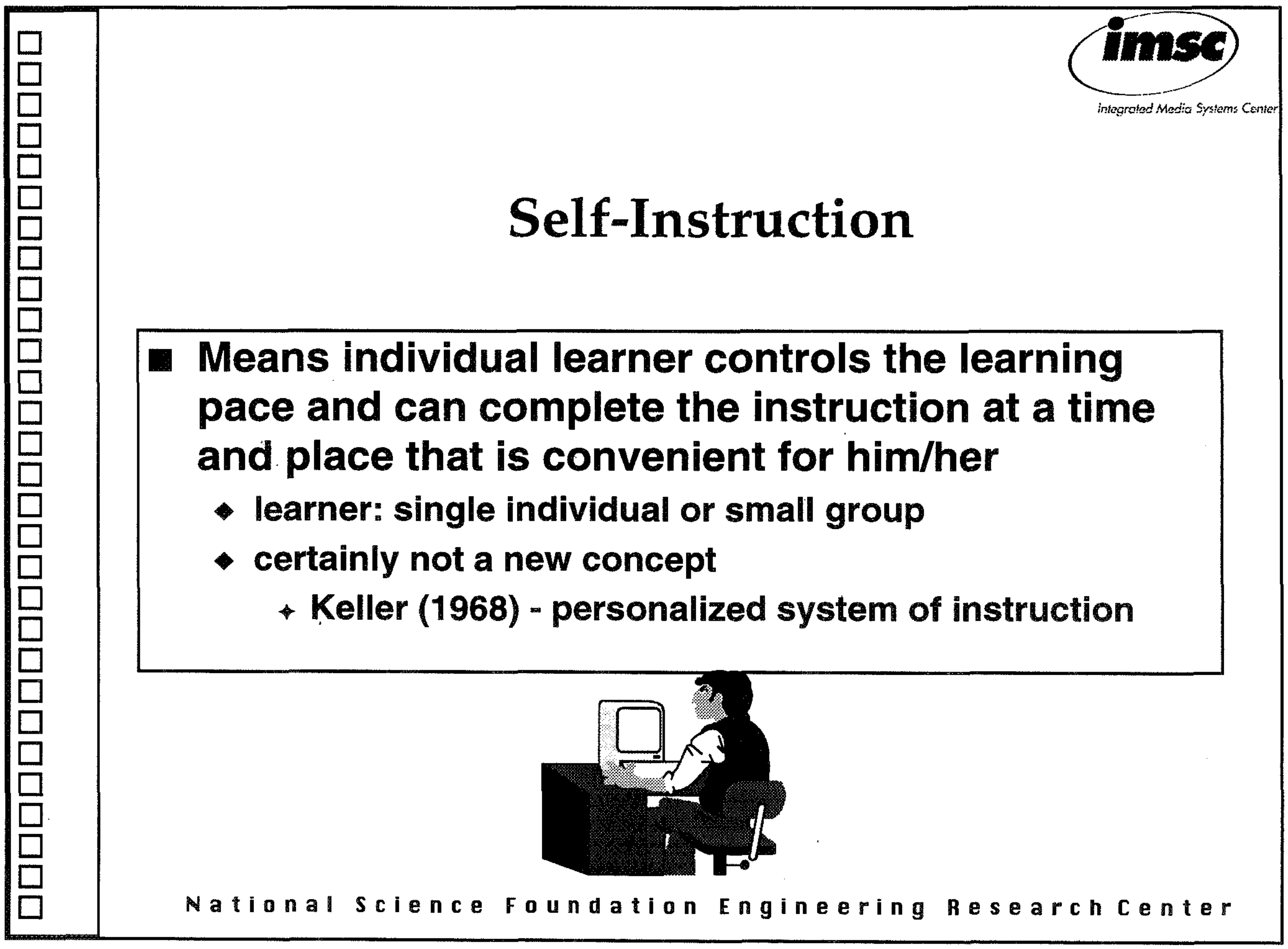
Self-Instruction

In this article, I propose to view interactive multimedia instruction as a form of *self-instruction* in that the learner controls the learning pace and can complete the instruction at a time and place that is convenient for him/her. The "learner" may be a single individual or a small group of individuals. Of course, self-instruction is not a new concept.

According to Driscoll (1996, p. 57), the concept of a "personalized system of instruction" (PSI) is due to Keller (1968). It is an alternative to group instruction, and is a form of self-instruction. In PSI, course *material is broken up into units, or modules, each with a set of behavioral objectives specifying what is to be learned in that unit. Units generally correspond with chapters in a textbook, so that they are taken up in a sequence.* PSI has strengths and weaknesses, which should be of interest to developers of multimedia modules for self-instruction.

One strength, individual study, is emphasized. One weakness is self-pacing, which can produce procrastination so that some students do not finish the requirements of the PSI course within the designated time period.



Two Questions

Before we decide to create a backbreaker-concept module, we need to answer two critical questions that focus on self-instruction: (1) Is self-instruction warranted for the learning objective (i.e., are criteria that focus mostly on the learner, and that establish a need for self-instruction, met)?; and (2) Are practical considerations for self-instruction that focus on the subject matter, resources, and the learner satisfied? Only if the answers to both questions are yes should we consider to take the next step in the creation of a multimedia module.

Gagnè and Medsker (1996, p. 184) provide four testable conditions for question 1 and six testable conditions for question 2. These questions as well as a critical analysis of them are found in Mendel (1998). The general conclusion is that the answers to questions 1 and 2 are "yes" for a backbreaker concept.

One of the conditions for quesion 1 is: Is mastery by each individual required? One of the conditions for question 2 is: Is the lifetime of the course long?

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Two Questions

- Is self-instruction warranted for the learning objective?
- Are practical considerations for self-instruction that focus on the subject matter, resources and the learner satisfied?
- Answers are "YES" for a backbreaker-concept, modulo a reinterpretation of some of the conditions associated with each question, subject to interactivity and backbreaker-concept

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Individualizing Self-Instruction

Once self-instruction is warranted, we need to know if existing ways for individualizing self-instruction apply to the development of an engineering module. Gagnè and Medsker (1996, p. 183) provide three ways for individualizing self-instruction: (1) assess prior knowledge to determine an individually-appropriate entry point, (2) self-select objectives to meet individual training needs, or (3) individualize prescription of learning activities to match a preferred learning style.

Assessing prior knowledge can be accomplished by means of a carefully designed questionnaire or quiz, or both. A module that lets the learner make choices about the route(s) he/she wants to take in order to reach the overall learning objective is a way for the learner to self-select objectives to meet his/her learning needs. Note, however, that the overall learning objective has already been established by the very nature of a "backbreaker concept," since these concepts are a direct result of students having great difficulty with them; and these backbreaker concepts must be learned by the students. That is the purpose of the module.

Individualizing the prescription of learning is discussed next.

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Individualizing Self-Instruction

- **Assess prior knowledge to determine an appropriate entry point**
  - questionnaire or quiz + software
- **Self-select objectives to meet individual training needs**
  - backbreaker-concept/learning map
- **Individualize prescription of learning activities to match a preferred learning style**

[Ref: Gagnè and Medsker (1996)]

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Multiple Models of Representation

Some learners visualize well, others do not; some absorb written material well, others do not; some absorb audio material well, others do not; etc. These groups need not be mutually exclusive, i.e., a person may learn well from written and visual materials but not from audio materials. Another person may learn well from visual and audio materials, but not from written materials. The problem with all of this, for a multimedia module, is that we do not know, and may never know, which modality is best for an individual. Hence, we must not throw out the baby with the bath water, so-to-speak, by abandoning learning from traditional media. We should augment what we are doing now with different media modalities in order to make learning possible for a larger group. Doing this is well documented in the educational literature [e.g., Driscoll (1996, p. 370)].

The learners should be given the opportunity to choose the modalities that work best for them; we should not decide that ahead of time.

So, a successful module needs to have its material presented in different ways using different media modalities.

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Multiple Models of Representation

- Not all learners learn well from the same modalities
- We do not know, and may never know, which modality is best for an individual
- Material should be presented in different ways using different modalities
- Learners should choose the media modalities that work best for them

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Which Media for Self-Instruction?

Gagnè and Medsker (1996, p. 181) have some very interesting, and perhaps surprising, comments to make about the question, "Does the medium used for instruction make any difference for learning?" They are highlighted in the figure below.

They then claim (p. 182) that, *it would be an overstatement to say that media selection does not matter* and *media selection remains an important contributor to the design of effective learning conditions*, both of which may seem somewhat surprising in light of the comments below. Not really though. Instruction must make use of at least one type of medium, so one interpretation of their statements is: try to choose the media that will let you do the best job. Of course, to do this, we must analyze the instructional task from different perspectives.

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Which Media for Self-Instruction?

- **"The medium used for self-instruction does not make any difference for learning"**
- **"Almost any medium can be used to teach almost any objective effectively"**
- **"The design of the underlying instructional message is more important than the communication channel chosen to transmit the message"**
- **Choose the media that will let you do the best job**

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Media Choices: 1

If we are preparing an interactive multimedia educational module, then it can involve a wide range of equipment, including: video of real equipment, capability for simulation, virtual reality, computer, video, animation, audio, presentation vugraphs or slides, and, videos of posters, charts, whiteboards, chalkboards, or flipcharts. Gagnè and Medsker (1996, p. 182) advocate that *the media chosen must be capable of transmitting the required stimulus features of the message*. For example, one would not teach animation without demonstrating it, nor would one teach about different types of sound systems without playing them. Additionally, they state (p. 183) that *if learners are to attend to the instruction and be receptive to it, learner characteristics must be matched.*

Individualizing the prescription of learning activities to match a preferred style of learning has been discussed above, where we concluded that the learners, not the developers of a multimedia module, should be given the opportunity to choose the modalities that work best for them. Because the developer can never know which modality works best for which individual learner, the module should present important ideas and concepts using different media modalities.

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Media Choices: 1

- **"The media chosen must be capable of transmitting the required stimulus features of the message"**
- **"If learners are to attend to the instruction and be receptive to it, learner characteristics must be matched"**

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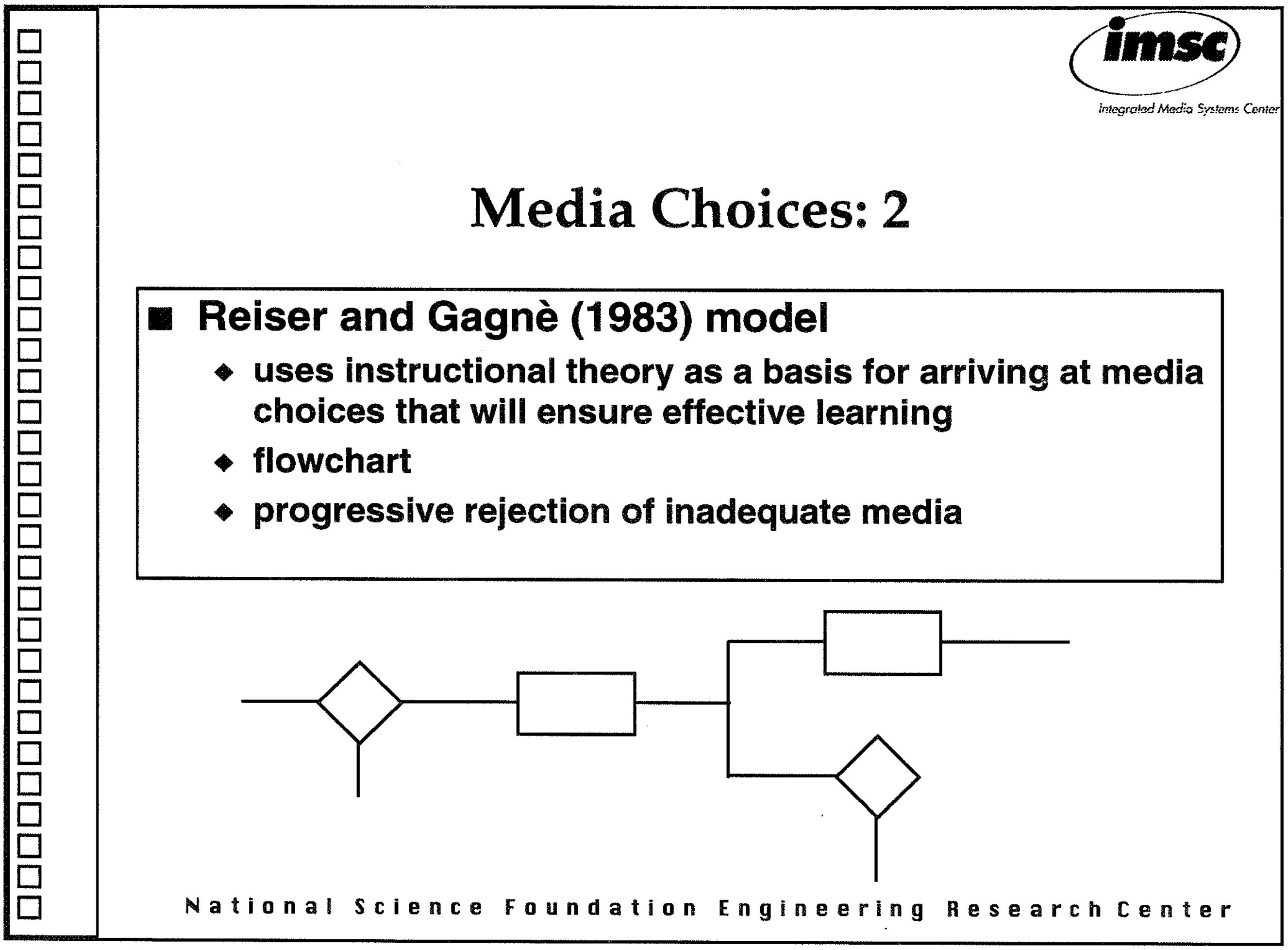
Media Choices: 2

A model known as the Reiser and Gagnè model (1983) uses instructional theory as a basis for arriving at media choices that will ensure effective learning. The model is flowcharted and employs a procedure of 'progressive rejection' of inadequate media.



For example, [Gagnè and Medsker (1996), Fig. 14-2]: if self-instruction is warranted (as we have already agreed, for a multimedia backbreaker-concept module), and the students are good readers, and the objective is to teach a mental skill, then their theory advocates the use of computer-based media, a programmed text, or interactive TV. Since much of what engineering students learn is covered by this statement, it surely supports the use of interactive multimedia for backbreaker concepts.

So, Reiser and Gagnè's media-choice model supports using interactive multimedia and I advocate its use for backbreaker-concept modules.

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Media Choices: 3

- **Example**
  - **self-instruction is warranted**
  - **students are good readers**
  - **objective is to teach a mental skill**
  - **their theory advocates use of:**
    - **computer-based media**
    - **programmed text**
    - **interactive TV**
  - **supports use of interactive multimedia for backbreaker-concepts**

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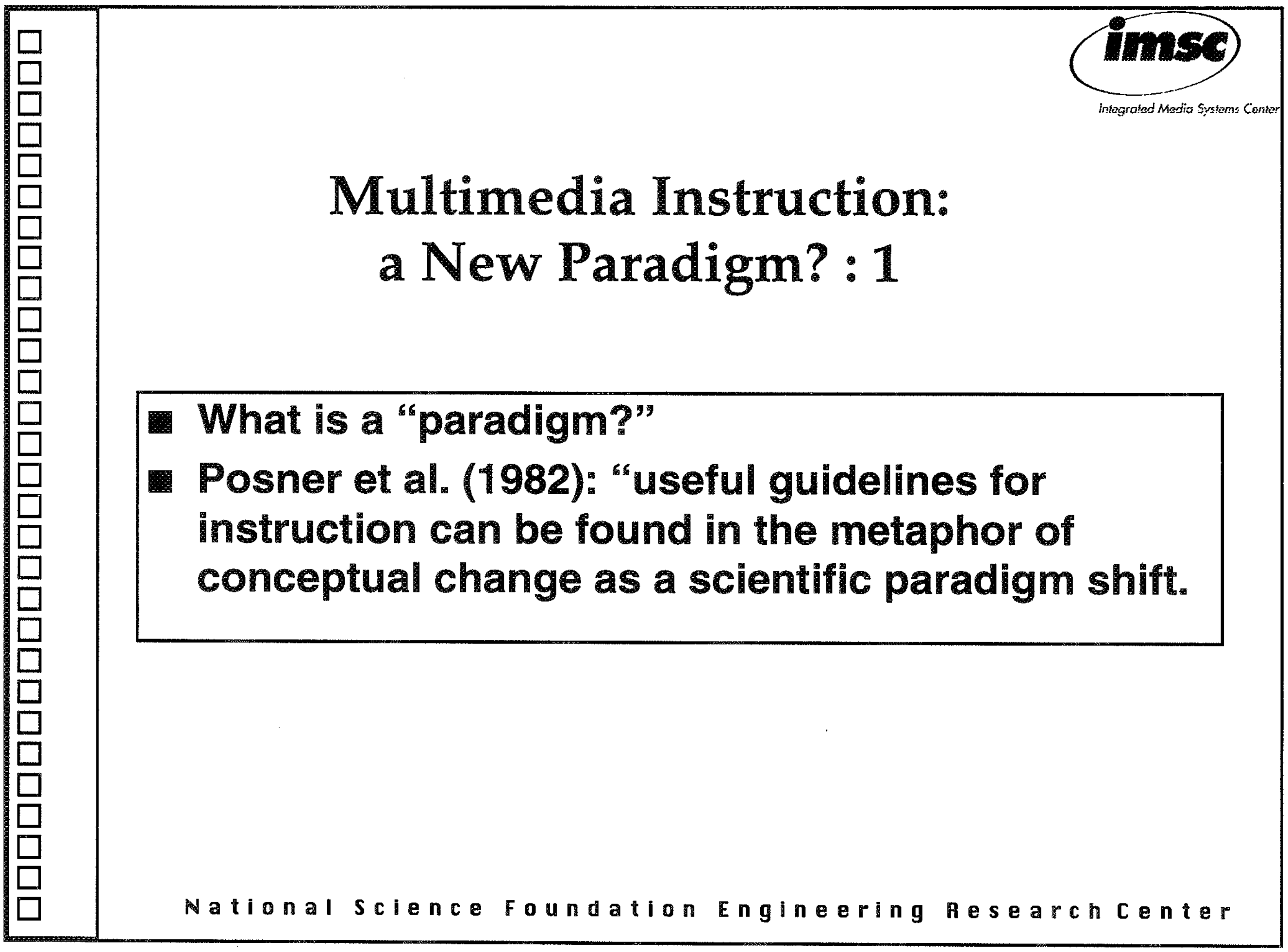
Multimedia Instruction: A New Paradigm?: 1

As a side point, many people refer to multimedia instruction as a "new educational paradigm. Is this the proper way to refer to multimedia instruction ?

To answer this question, we must first understand what a "paradigm" is, and then we must examine whether "multimedia instruction" satisfies the conditions of a paradigm.

This figure and the subsequent one describe what is meant by a paradigm.



Multimedia Instruction: A New Paradigm?: 2

The four items listed below can be tested to see if "multimedia instruction" is a "paradigm."

First, we need to establish the "concept" with which educators are dissatisfied. I argue in [Mendel (1998)] that it is not: self-instruction, the use of instructional media, interactivity, or learning theory (instruction theory is built on the foundations of learning theories, but is itself not a learning theory). So, what is it about multimedia instruction that warrants, or does it warrant, being referred to as a new paradigm? To finally answer this question, we have to understand the difference between linear and nonlinear instruction. Nonlinear instruction is well suited for self-instruction. Nonlinear instruction can be implemented using interactive multimedia. So, from a paradigm point of view, it is nonlinear instruction that deserves to be called a new instructional paradigm. It satisfies Posner's four requirements for a paradigm.

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Multimedia Instruction: a New Paradigm? : 2

- "New scientific conceptions emerge when:
  - there is existing dissatisfaction with the old conception
  - a new conception can be grasped
  - the new conception appears plausible
  - the new conception opens up new areas of inquiry"

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Multimedia Instruction: A New Paradigm?: 3

But, is nonlinear instruction a *new* paradigm? Driscoll (1996, pp. 58-59) has a brief accounting of early computer-based instruction. Programmed instruction to teach academic skills was proposed by Skinner (1958); however, his approach in which students progressed in small steps, called frames, was a linear one, in that all students had to work through the frames in the same order. Driscoll states (p. 59): *To improve on this linear style of program, Crowder (1960) introduced the notion of branching. In branching programs, frames are larger and are typically followed by questions with several possible answer options. Depending on how students answer a given question, they are branched to another segment of the program. In this way, students who know the material already may skip quickly ahead to new material. Likewise, students having difficulty with the instruction may be branched to remedial segments, which provide additional information and practice.* Clearly, "nonlinear instruction" is synonymous with "branching." So, the nonlinear instruction paradigm is not new. Multimedia instruction is a way to implement the paradigm of nonlinear instruction. So multimedia instruction is an implementation and not a paradigm. It is, therefore, proper to refer to interactive multimedia that is used for self-instruction as "multimedia instruction." A multimedia module should be prepared using the nonlinear instruction paradigm.

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Multimedia Instruction: a New Paradigm? : 3

- Multimedia instruction is not a new "paradigm" for instruction
- Nonlinear instruction deserves to be called an instructional paradigm
  - even it is not "new" e.g., Crowder (1960)
- Multimedia instruction is a way to implement the paradigm of nonlinear instruction
- Interactive multimedia used for self-instruction ⇨ "multimedia instruction"

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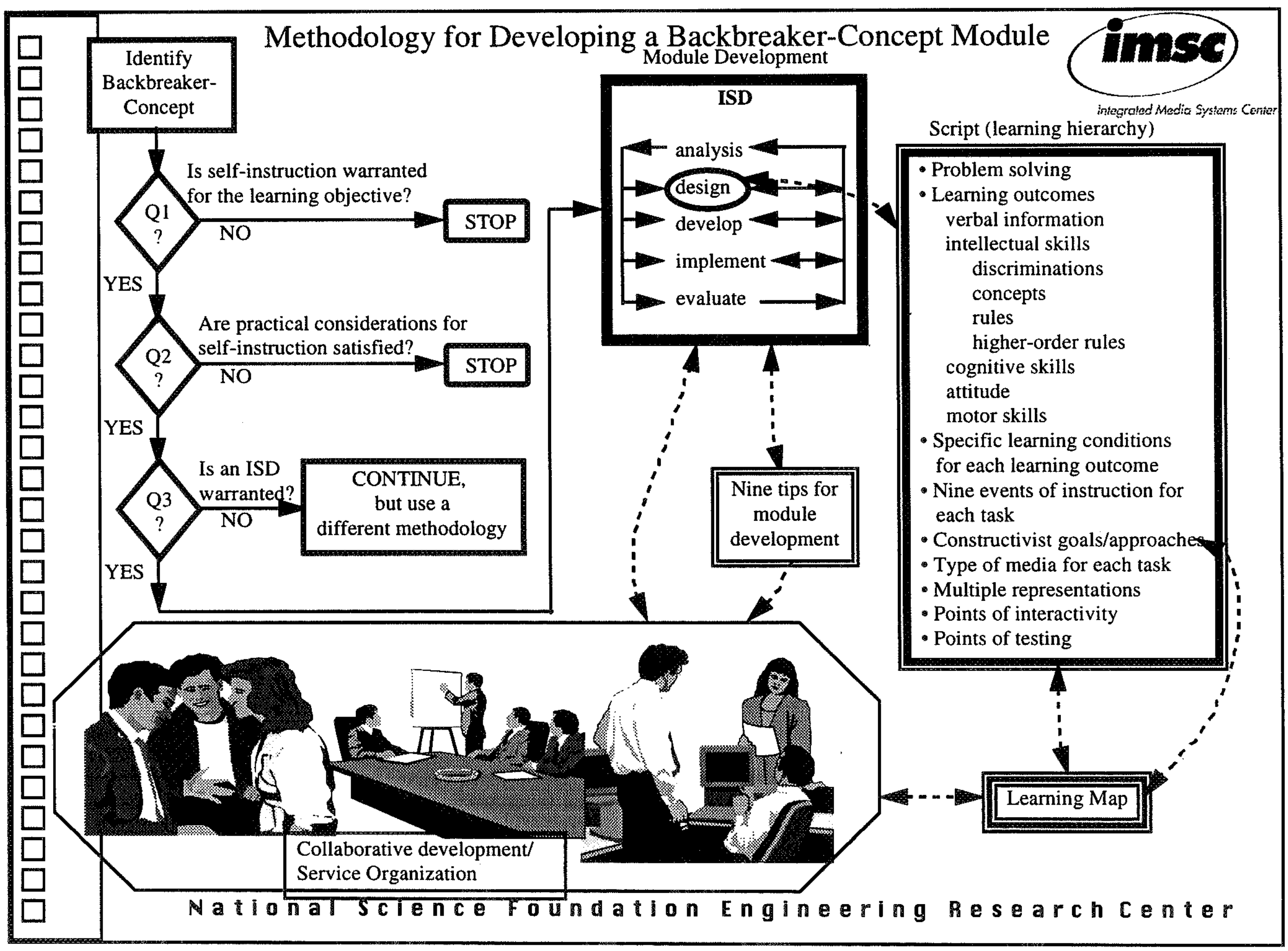
Methodology for Developing A Backbreaker-Concept Module

After it has been established that self-instruction and interactive multimedia instruction are warranted for a specific backbreaker-concept, the module developer's work really begins. A module should be designed using a methodology. Engineering educators who develop modules do not have to reinvent instructional training theories. They can read about them in the Education literature. In Mendel (1998), I describe (in great detail) a *systems approach,* Instructional System Design (ISD), to training, for the development of modules, due to Gagnè. The figure below summarizes this approach; but, space does not permit explanation in any detail.

The creation of a hierarchical skills script is essential; the script should be augmented to include the type of media used to learn each skill, points of interactivity between learner and module, locations of ungraded or graded quizzes, etc. Understanding the nature of the learning outcome (e.g., intellectual skill such as a rule) for each skill on the script will help the developer create a successful module. Adhering to the nine events of instruction will also help to ensure success, as will understanding and incorporating the key features of problem solving and ways for increasing the accessibility of problem-solving skills. Finally, a learning map will help individualize the module and will make it useful for beginners and more advanced users.



Learning Map

In a traditional education setting, a learning hierarchy is used by the teacher, but is not revealed as such to the learner; it is used by the teacher to develop the lesson plan, and is, in effect, a means to an end. I propose that individualization of a backbreaker-concept module can be accomplished by providing the learner with a learning map, which is an interactive map that lets the learner enter the module at his/her self-defined entry point, and suggests a route to reach the learning objective, but lets the learner change the route in real time.

Learning maps for backbreaker-concepts do not yet exist, so the module developer must play the role of mapmaker. The learning map builds upon a hierarchical skills script in that it creates different locations and routes based on the script.

Where do instructional techniques fit into all of this? I view an instructional technique as the vehicle that will be used to traverse pathways on the learning map. Just as many different types of vehicles traverse our highways, roadways and byways, different instructional techniques can be used to traverse learning pathways. So, the module designer cannot only create the learning map, which gives the learner choices about different paths to go from a starting state to a destination state, but he can also give the learner choices for the instructional technique to use to do this.

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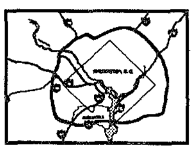
Learning Map

- **Is an interactive map that lets the learner enter a module at his/her self-defined entry point, and suggests a route to reach the learning objective, but lets the learner change the route in real time**
- **It has roadways that connect starting and destination knowledge points**
- **Instructional techniques are the vehicles that let us traverse pathways on the learning map**



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Instructional Techniques

So far, I have focused exclusively on ISD, which is closely related to objectivist instructional techniques; however, the learning map is not a part of ISD, and it will let a backbreaker-concept module be individualized. Since a learning map is not part of a traditional systems approach to instruction, and it seems like a good idea (at least to me), I am interested to know whether it will also let the module designer use other pedagogical principles (e.g., constructivism) as part of the design process.

According to Honebein (1996): *Designers of constructivist learning environments live by seven pedagogical goals ....: (1) Provide experience with the knowledge construction process; (2) Provide experience in and appreciation for multiple perspectives; (3) Embed learning in realistic and relevant contexts; (4) Encourage ownership and voice in the learning process; (5) Embed learning in social experience; (6) Encourage the use of multiple modes of representation; and (7) Encourage self-awareness of the knowledge construction process.*

In Mendel (1998), these seven goals are analyzed, one by one, in order to see which can possibly be incorporated into a backbreaker-concept module that includes a learning map. My overall conclusions are that, if we are permitted to deviate from the purest forms of constructivist pedagogical goals, then the use of modified (limited) goals may greatly enhance the module. A learning map seems to be the vehicle needed to do any or all of this.

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Instructional Techniques

- **Instructional system design**
  - rooted in "objectivism"
  - need to go past the hierarchy of skills (script)
  - interactivity and the learning map
- **Interactivity and other constructivistic pedagogical goals**
  - Learning map lets us use modified versions
- **Learning map lets module developer use objectivist or constructivist vehicles**

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Some Tips (Fred Betz, NSF): 1

Dr. Fred Betz, a National Science Foundation Program Director, who has supported the development of many engineering multimedia instructional modules (not necessarily for backbreaker concepts), gives nine prescriptions for successful module development. These are listed on the figure below and on the next two figures that follow.

Animation gobbles up a huge amount of preparation time and/or memory. Use it only if it is really needed.

People like to hear talking. Driscoll (1996, p. 315) suggests using two or more narrators and varying the format (e.g., conversation or interview as opposed to narration) to make the audio more interesting so that students maintain their interest in the material and do not let their attention wander.

Ideally, you should include testing about "WHY you didn't learn the content;" this may be too difficult or impossible to do using available tools and technology but is something to strive for.

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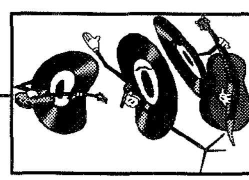
Some Tips (Fred Betz, NSF): 1

- **Motivate subjects with real applications and experimental content**
  - database of meaningful applications
  - use simulations and not animations
- **Include voice over text**
  - give user the option to use either
- **Include testing for content**
- **Give people choice of music**
  - not everyone likes same type of music



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Some Tips (Fred Betz, NSF): 2

The model used by most people for producing multimedia software is wrong! A correct model is a concurrent one that involves the faculty, programmer, and test customers all at once; the worst modules are those designed by a faculty person who then turns it over to a programmer, after which it is tested by an end user, in that order.

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Some Tips (Fred Betz, NSF): 2

- **Table of contents should be an option**
  - **don't start the module with it (boring!)**
- **Use a production support system for creating the module**
- **Model used by most people for producing multimedia software is wrong**
  - **should be a concurrent model**
    - **involve faculty, programmer and test customers all at once**

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Some Tips (Fred Betz, NSF): 3

The remaining two items are self-explanatory.

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Some Tips (Fred Betz, NSF): 3

- Assessment must be built into the module as it is being created, not after it's created
- Modules should have links (hot buttons) to provide in-depth learning
  - Learning Map

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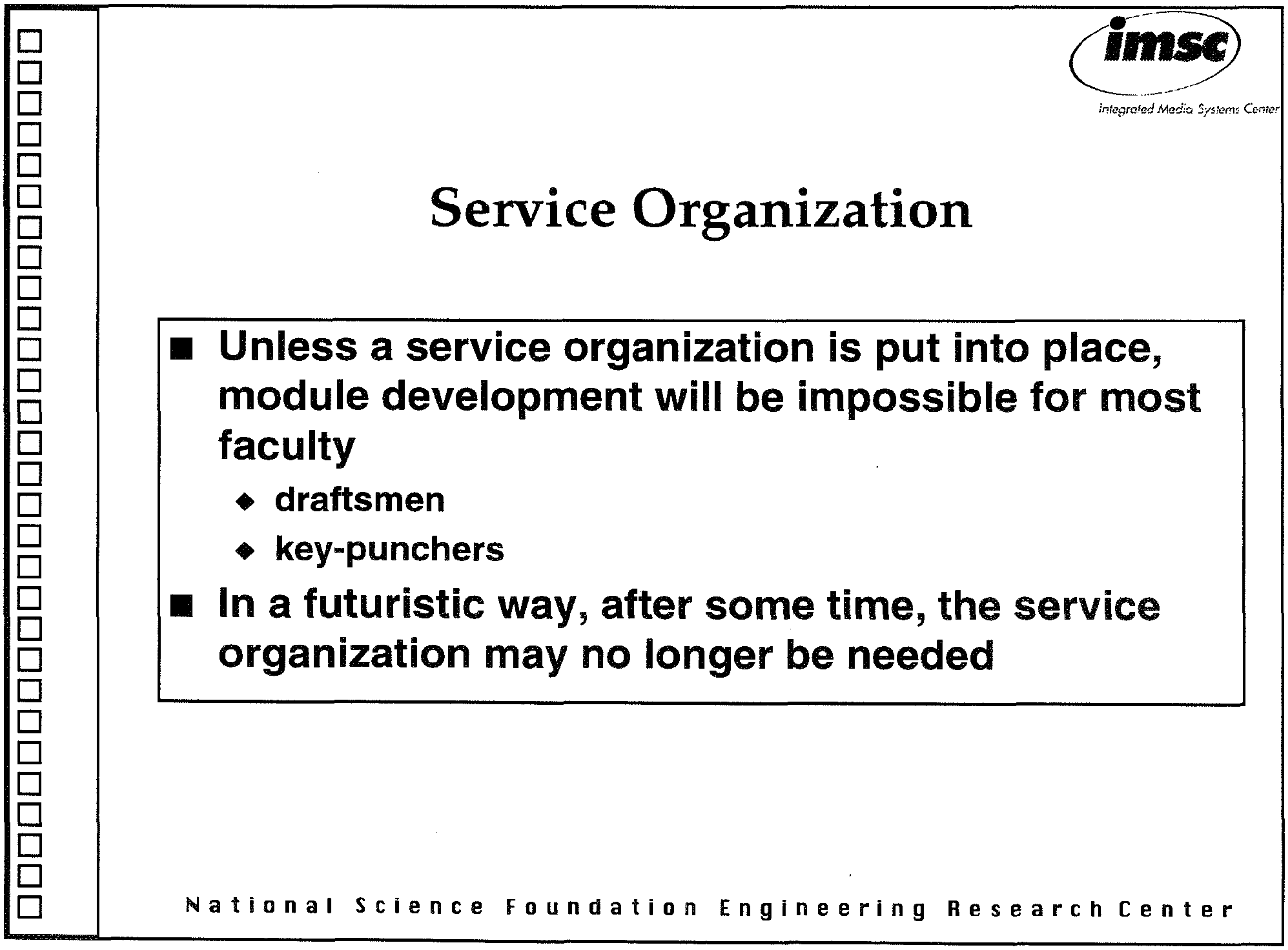
Service Organization

Developing an interactive multimedia module is very different than writing a set of lecture notes or even a book. Most faculty today cannot do it all themselves. It needs to be done in a collaborative environment. In earlier times, we had draftsmen and keypunchers who helped us get our work done. The desktop computer and its associated software have made them obsolete; but, there was a significant interval of time when we could not have gotten our work done without them. They were usually part of a service organization.

There is a need for a service organization within a school of engineering that will work jointly with the module "developer" to create the final product. Unless such an organization is put into place, module development will be impossible for most faculty.

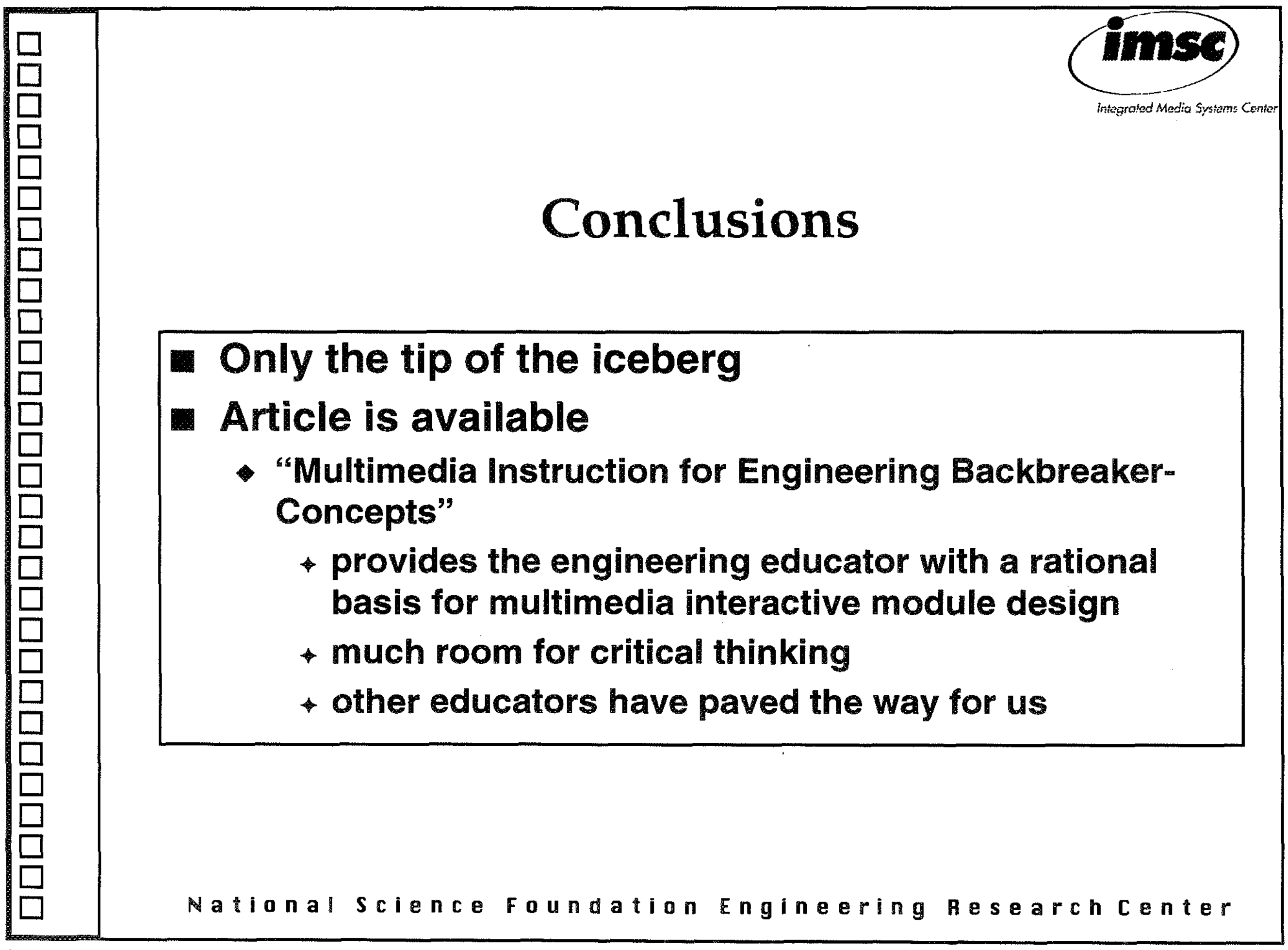
In a futuristic way, after some time, the service organization may no longer be needed, just as it no longer provides draftsmen or key punchers. It may give way to a new breed of faculty, computers and software, that will make the creation of a module possible by an individual.



Conclusions

Hopefully, this article provides the engineering educator with a rational basis for multimedia interactive module design, and demonstrates that there is much room for critical thinking and that other educators have paved the way for us.

Again, the details can be found in Mendel (1998).



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- **References mentioned on the figures, or in the accompanying text above the figures, are listed above this figure and are continued at the top of the next page.**

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References: 2

- **References are continued at the top of this page**

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Increasing Interactivity in Engineering Education

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Increasing Interactivity in Engineering Education

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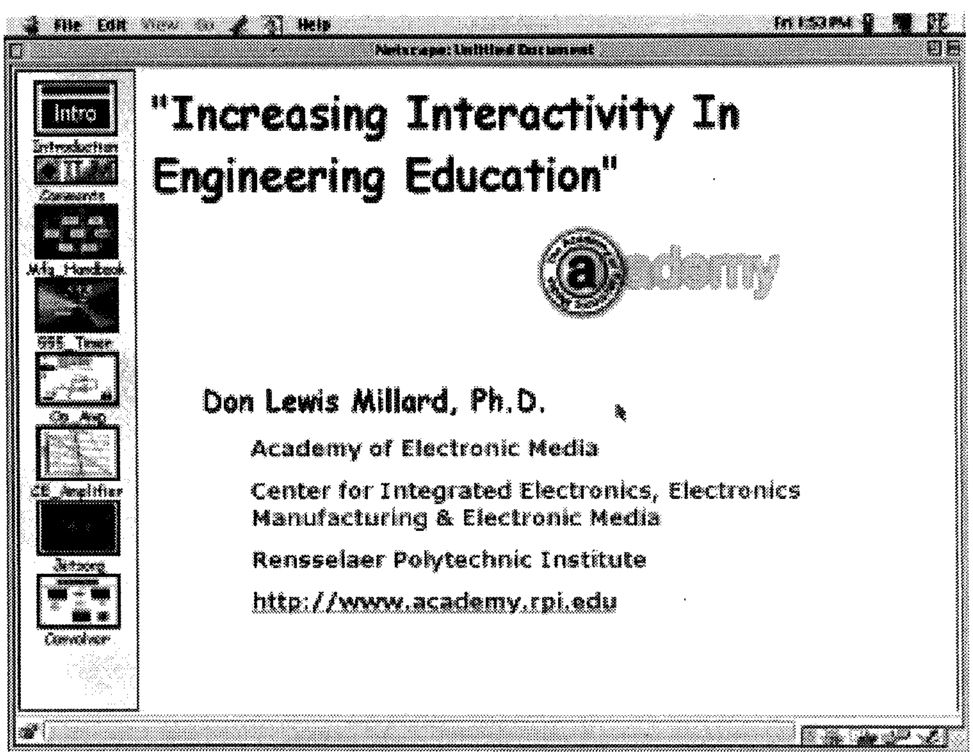
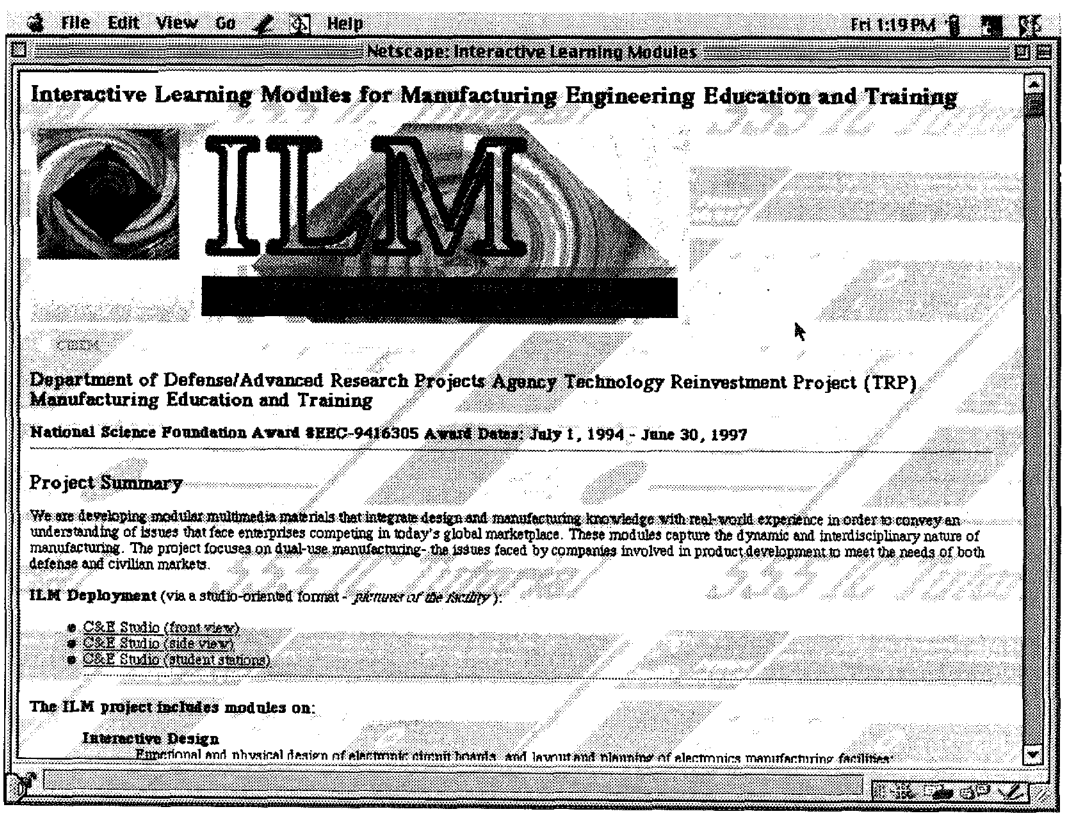
Computers are now an integral part of our day-to-day regime and prevalent in all aspects of our society. Yet with all this available technology, we have only begun to scratch the surface of harnessing the influence and power of the microprocessor. The development and use of engaging interactive electronic media that simultaneously stimulate multiple senses will revolutionize the way in which knowledge is garnered and technology is utilized at all levels - from young child to life long learner. We believe this revolution in education will be significantly accelerated by widely distributing highly interactive, information-rich multimedia that both engages and captivates the user. Traditional materials and methods of delivering education no longer provide the insight necessary to be effective within the dynamic and interdisciplinary nature of today's highly technical environment. Increased use of interactive multimedia allows us to integrate the most current analytical, modeling, visualization and decision-making processes associated with real-world applications with greater hope of achieving success in shorter cycles, using learning technologies, virtual simulations, web-based environments and interactive materials to aid those competing in an increasingly technical and global market.



RPI's Studio/ILM Model

The model being developed in the Electrical, Computer and Systems Engineering (ECSE) Department at Rensselaer involves the use of Web-based, interactive multimedia materials in conjunction with a Studio format of course delivery. Interactive learning modules (ILMs) are used in Studio classes by faculty to help explain concepts and demonstrate applications, and by students for specific learning exercises. Outside of class, the ILMs are available from anywhere at anytime over the Internet, using either public or private computing resources. They are used by students for more in-depth exploration of concepts and interactive practice with design and problem-solving activities. The basic goal is to develop easy to use, highly interactive materials ***which simultaneously stimulate multiple senses.*** The student (or adult learner since the materials can be used for multiple purposes including technical training) is first presented with the context of the material and hopefully attracted to *peel off successive layers of the onion* to gain a full understanding of the basic theory, principles and concepts. Additionally, the student is encouraged to *play* in a highly interactive, highly-functional design space where he/she can get immediate answers to *what if* questions and develop the problem-solving and design skills that are such a valuable component of an engineering education. We have begun using this model of combining ILMs and the Studio format in both a Circuit Analysis and an Analog Electronics course during the 1996/97 academic year and are extremely pleased with the initial results. We believe this approach can provide a fundamentally different model for engineering education.



ILM Homepage

ILM Development and Content

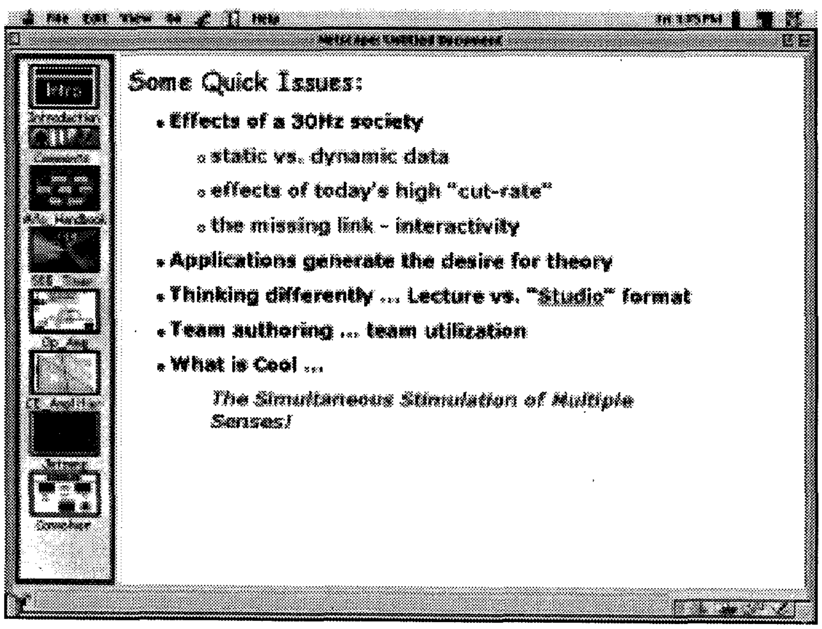
Our development objective is to create interactive materials that combine graphics, animations, audio/video, modeling and simulation in an enticing environment that allows the user to understand how electronic circuits: 1) are designed, 2) operate, 3) are manufactured, and 4) can be utilized in real-life applications. The ILMs pick up where most textbooks leave off, via the use of multimedia, to additionally allow the user to explore and understand the dynamic nature of how electronic circuits are designed, manufactured and applied. For example, the capability to see and hear the result of how an amplifier increases the amplitude and volume on an input signal provides the user with a much more powerful understanding of the circuit operation. The hope is that this integrated presentation approach will ultimately generate a much greater impact than that which single-dimensional books or static web pages can accomplish. ILMs are generally organized into three sections:

1) *An introduction* - which includes (nominally three) interactive examples of applications, introductory text, graphics, etc., and background tutorial material-sense of *real-life* configurations available;

2) *A design, experimentation and analysis "playspace"* - which allows the user to design and test circuits in a series of highly interactive models via an analytical engine that can process chosen input(s) and generate output (in the form of graphic plots, audible signals, etc.);

3) *Problem sessions* - consisting of specifically tailored problems are provided for solution (in a manner that allows the user to utilize the analytical engines from the prior section to explore their understanding of the material) and providing on-line guidance and aid (when progress deems it necessary).

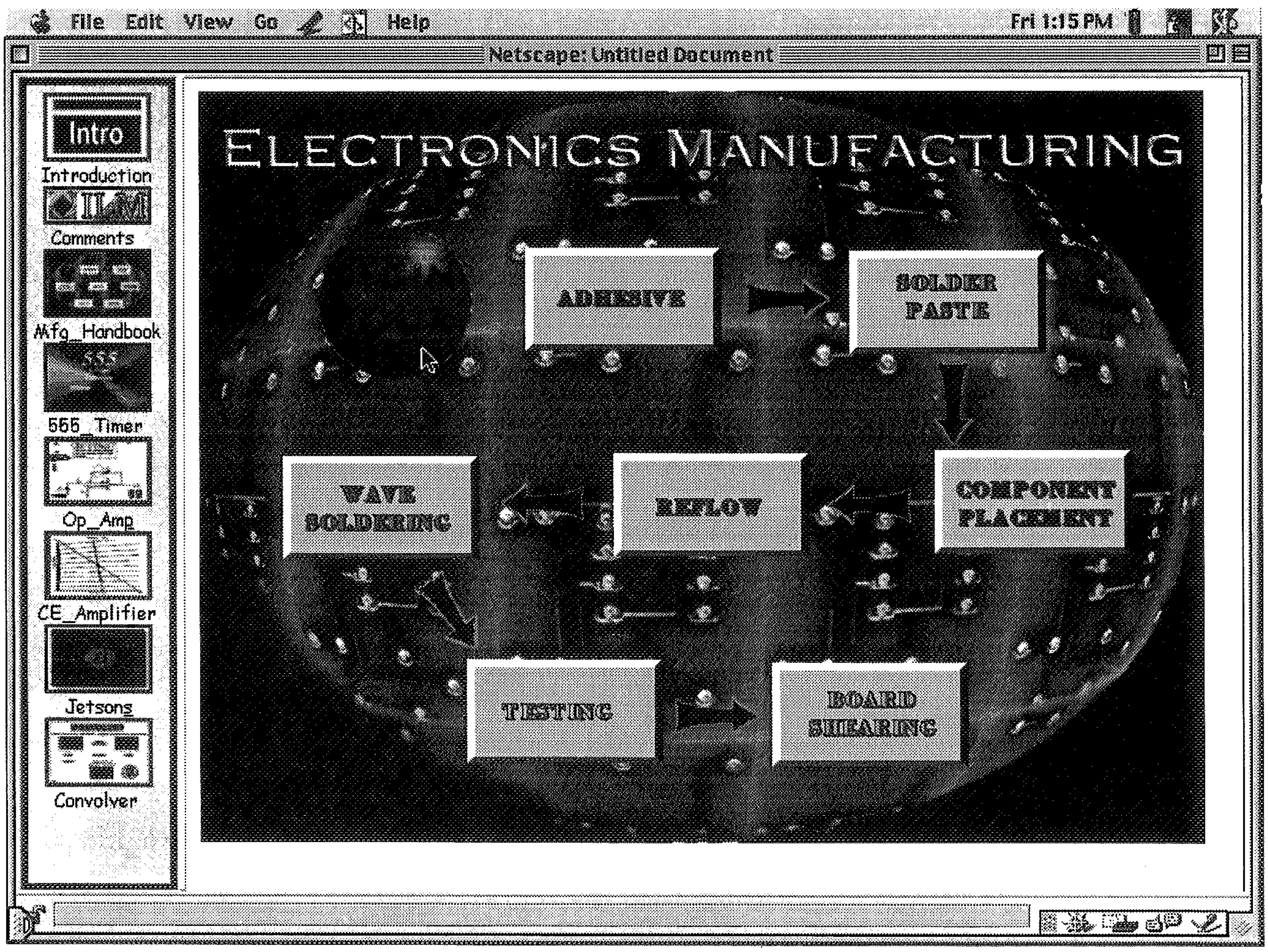
Many of the Academy's Interactive Learning Modules (ILMs) are already available on the Internet, and can be accessed via http://www.academy.rpi.edu. The following sections describe some of these ILMs.



ILM Developmental Issues

Manufacturing Handbook:

An electronics manufacturing handbook has been developed that offers animated presentations of current printed wiring board assembly processes. A prototype presentation of the equipment and processes used in NorTel's RTP facility has been developed to give the user a sense of actual electronics production. Video footage is organized in a manner that shows the flow of production at the facility and the correspondence with the training oriented animated presentations. The user can select a process from a graphical interface that depicts the flow of the production and further choose to view an animation, video or ultimately virtual reality interactive presentations (using QTVR to "fly through the manufacturing floor" and view the design at various stages of the manufacturing process).



Main screen from the Electronics Manufacturing Handbook

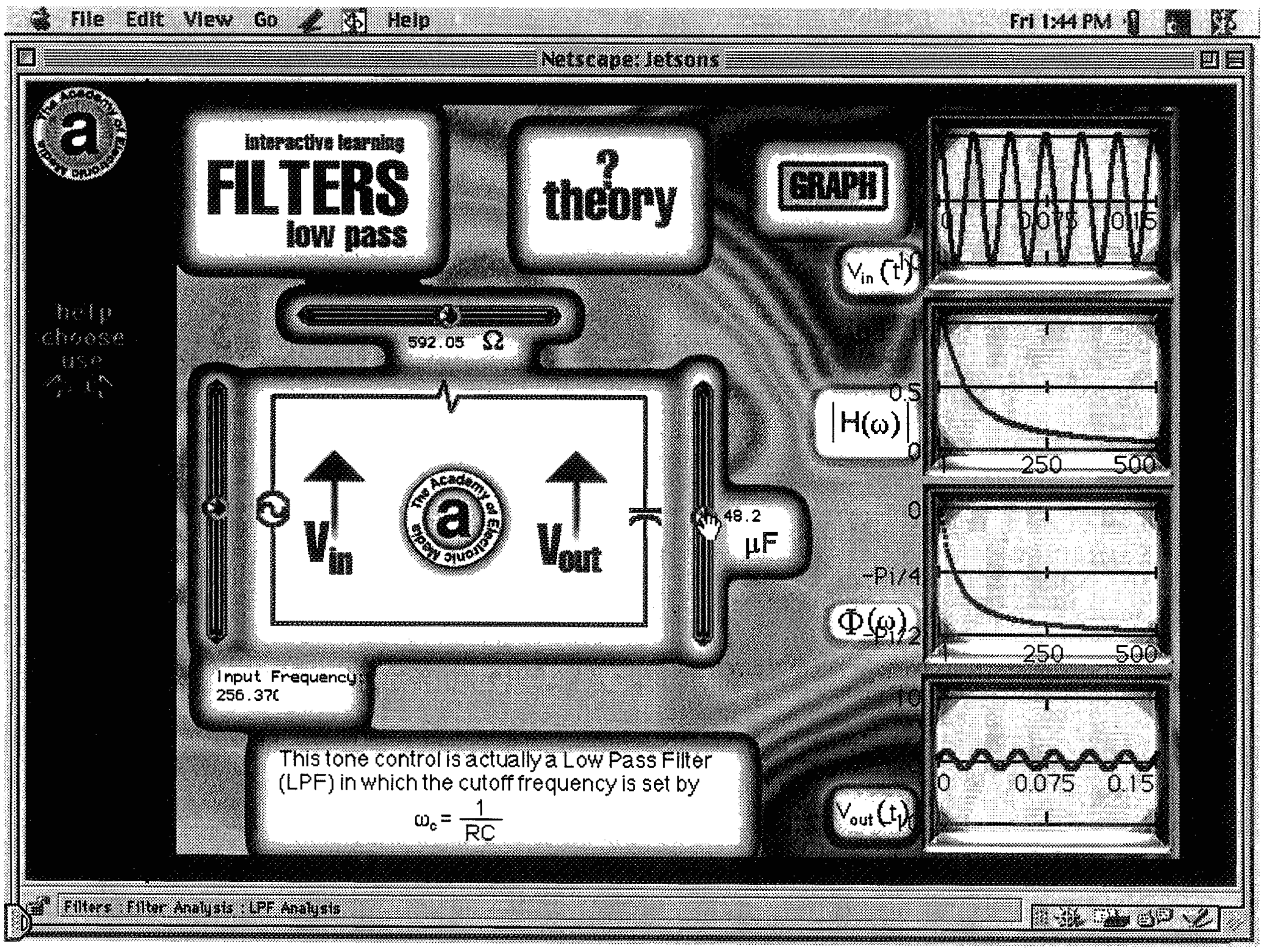
EE Handbook:

An EE handbook has been developed to offer descriptive presentations of a number of electrical engineering related topics, again in various levels of depth. For example, the electronic filters section presents the user with both a high level view of what a filter does and a lower level description of the corresponding circuit elements that filter electronic signals. These materials are intended, both as a stand-alone handbook and, in conjunction with a particular circuit module, as introductory and tutorial background materials (e.g., as a contextual precursor to the more comprehensive "EE Filters" module).

Overview of High Pass Filters
Example from the Handbook

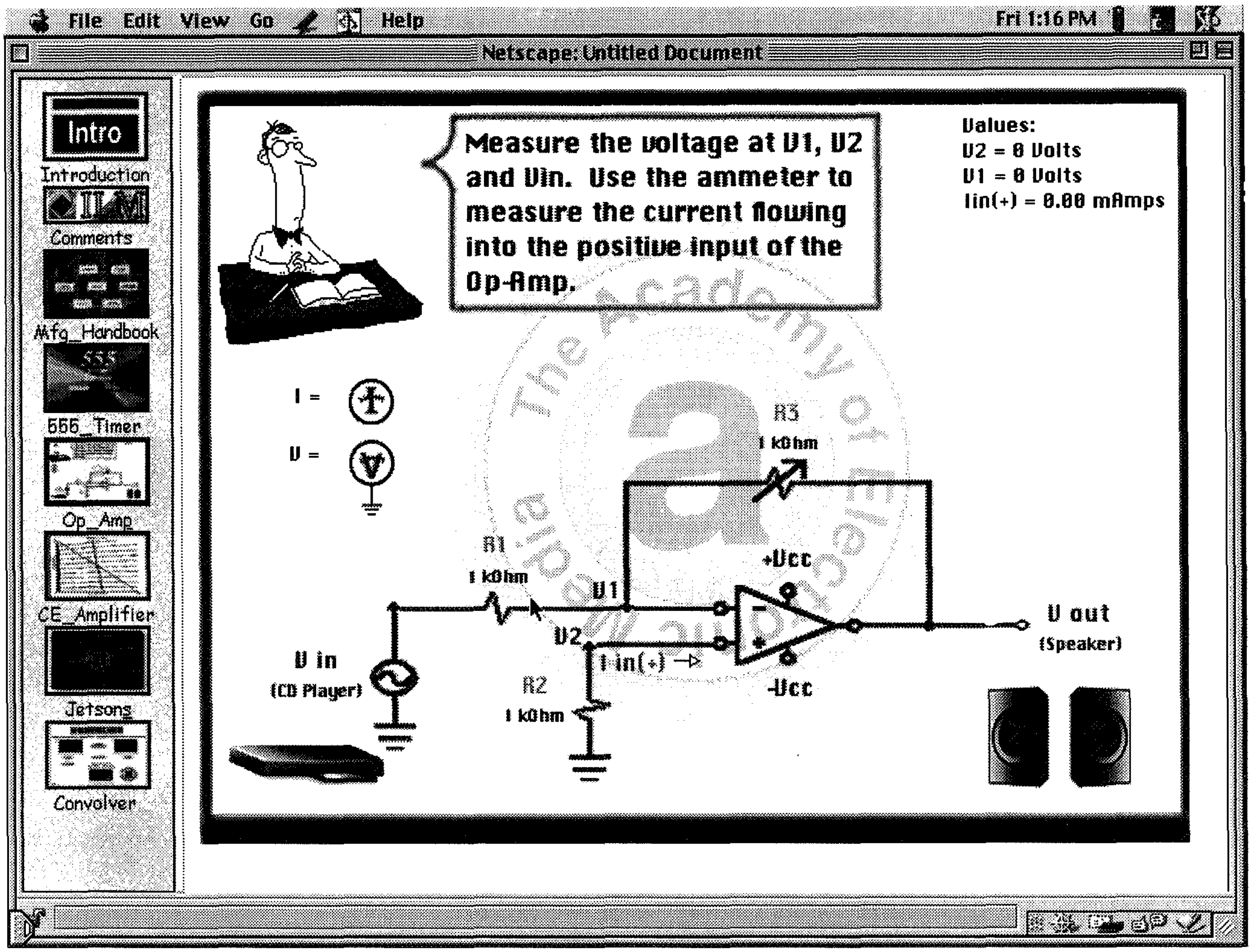
Electronic Filters:

This module provides the user with an understanding of how circuits can be designed to tailor the frequency response of electrical signals. The capability for designing and testing a variety of single and higher-order filters is available along with a means to allow the user to watch and listen to the output resulting from their circuit's effect on a chosen input signal(s). The current implementation includes low-pass, high-pass, and band-pass passive circuits. The frequency and overall time domain responses can be viewed simultaneously, thus providing the user with a relationship between the frequency and time domains.



Low Pass Filter "Playspace" Screen:

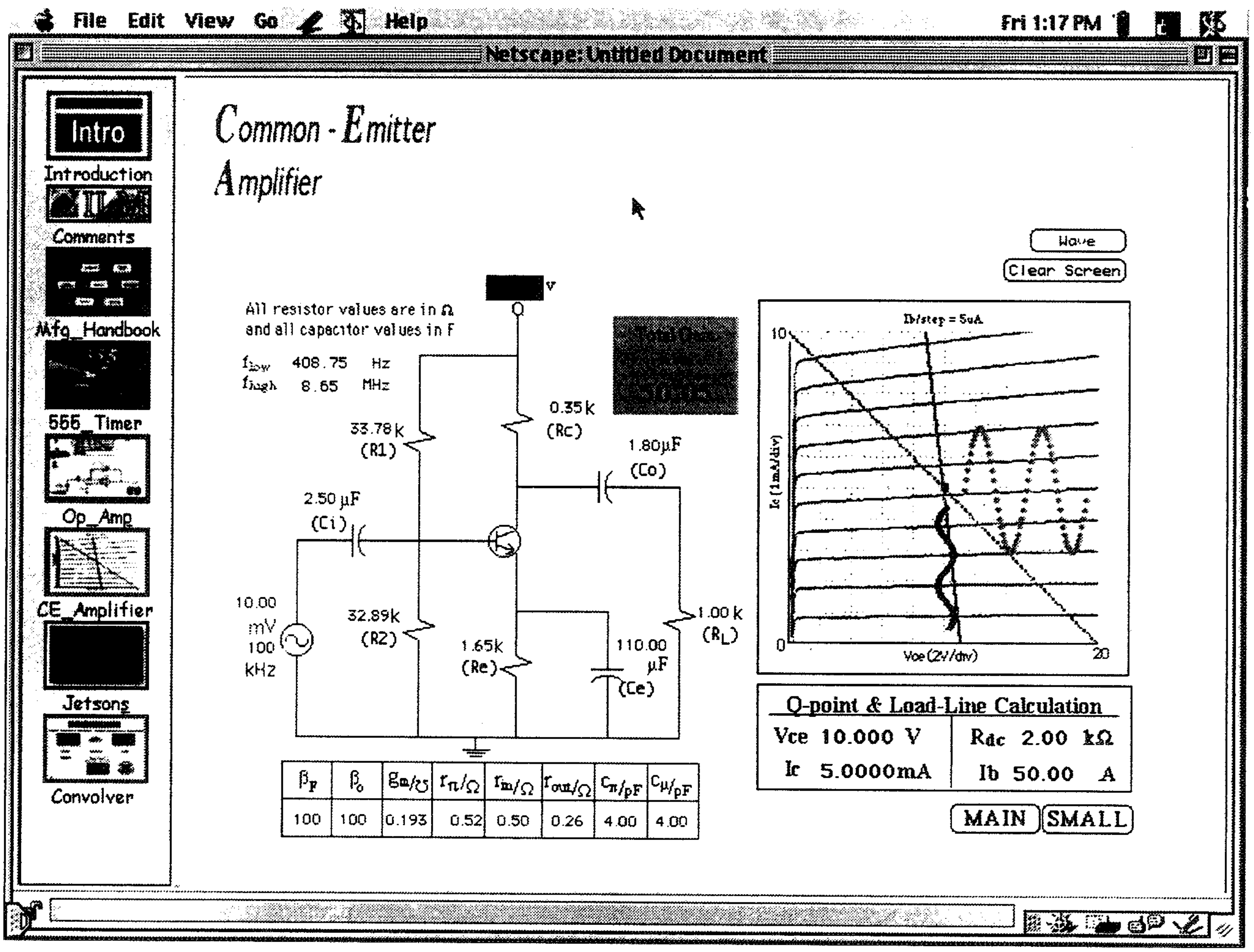
The operational amplifier module allows the user to design and analyze various op-amp circuits via a combination of visual and audible input/output signals. Over fifteen configurations are available for analysis, thus providing a rich suite of circuits for students to use in their challenges provided in the section's corresponding problem session. In addition, the concept of device saturation (due to inappropriate DC supply choices), along with the resulting distorted output, can be explored by the user examining the trade-off between the amplifier's gain and Vcc.



Op Amp "Measure and Discover" Module Screen

Transistor Amplifiers

An NPN bipolar junction transistor amplifier has been used as the foundation for this module, in which the user can investigate the basics associated with the characteristics, DC biasing, and configuration as a small signal amplifier. A highly interactive screen allows the user to investigate DC biasing via pointing and clicking. The module enables the user to immediately observe the shifts in the amplifier gain induced by altering either the quiescent (Q) operating point or the amplifier resistances and then viewing the resulting effect (visually and audibly) through amplification of an AC input signal.

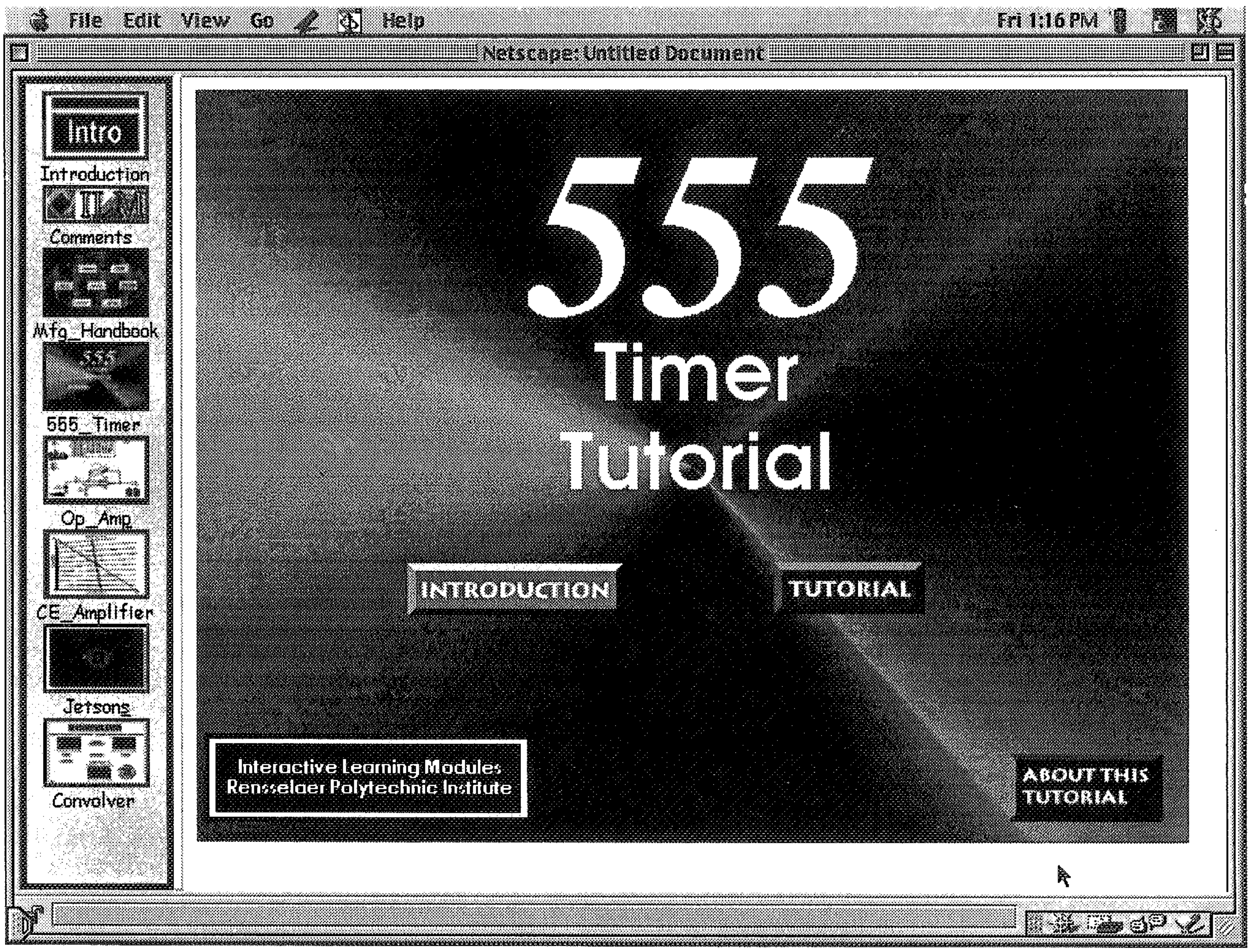


β_F	β_o	g_m/℧	r_π/Ω	r_m/Ω	r_{out}/Ω	C_π/pF	C_μ/pF
100	100	0.193	0.52	0.50	0.26	4.00	4.00

Common Emitter Amplifier Screen

555 Integrated Circuit:

This module presents the operation and application of the popular and versatile "555" timer integrated circuit. Astable and monostable configurations of the circuit are available to exhibit the timing circuits associated with oscillators and single pulse generation. The user can, in effect, peel the top off the chip to look inside and see what is going on (as seen in the figure below). A series of double clicking takes the user down sequentially through all the functional levels of the IC to gain a very basic understanding of how the circuit's output signal evolves over time.

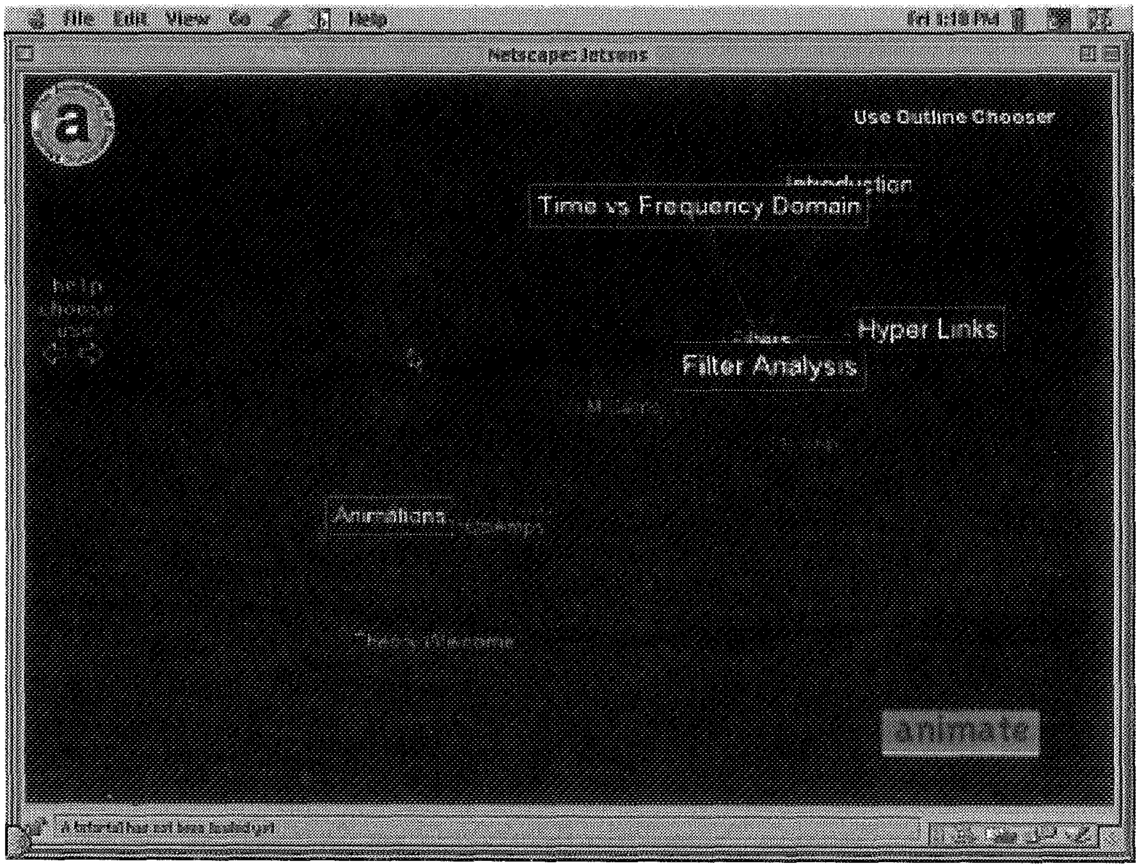


555 Timer Introductory Screen

Impact and Future Plans

Students clearly see the use of ILMs as more *fun* than traditional paper and pencil problems, and enjoy being able to explore concepts in the context of real-life applications. Overall student satisfaction levels with the ILMs, as measured by surveys, is quite high. We believe the students will learn more and retain more, although it is still too early to have definitive data on the specific learning effects of the ILMs. The early results of the combined ILM/Studio approach have been so encouraging that the ECSE faculty has voted to move all eight introductory courses (typical enrollment = 80-150 per term) in Electrical Engineering and Computer and Systems Engineering to this format, and eliminate several required laboratory courses from the curricula.

This is just the beginning of an interactive multimedia era at Rensselaer. Experience with both success and failure garnered from developing ILM structures and strategies will be utilized to further aid others in their pursuits of interactive learning. This is an area in which Rensselaer is making a major contribution to the way future students are educated and trained. Future progress in this arena is not dependent on vast resources, but on a commitment among faculty and staff to develop the most effective materials and methods possible, and to maximize their utilization in every appropriate avenue. Rensselaer has made that commitment.



The Academy's "Jetsons" Architecture

Dynamic Generation of Individualized Education

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Dynamic Generation of Individualized Education

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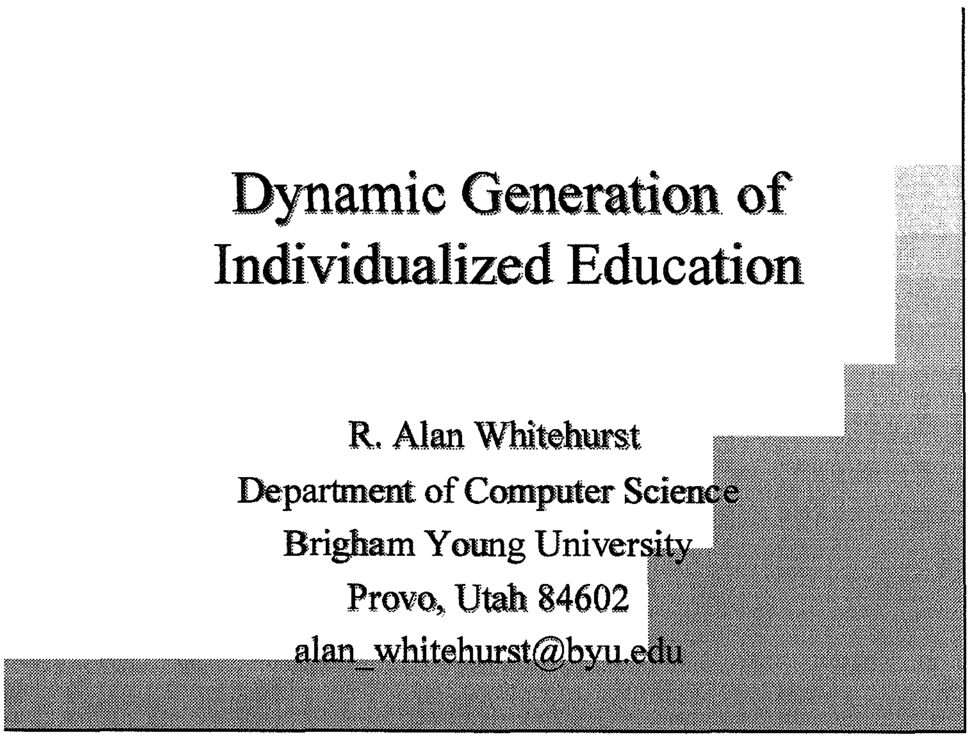


Optimizing Educational Effectiveness

A number of social and economic pressures are reshaping the way we approach education. It is clear that we must do a better job of responding to the demand for highly qualified scientific and technical workers if we are to meet the challenges of the coming century. At the same time, educational budgets have not been keeping pace with the rising costs of providing a high-quality conventional education. Thus, the challenge is to "do more, with less." In short, we must find a way to increase the quality of the education we are providing while simultaneously decreasing the cost of delivering that education. In order to increase educational quality, we must find a way to teach that is responsive to the needs of the individual. To decrease the cost of providing education, we must become more adept at sharing and reusing educational resources. Fortunately, both these goals share a common solution: augment conventional instruction with the ability to dynamically generate and deliver individualized education from a repository of reusable educational components.

Do MORE with LESS

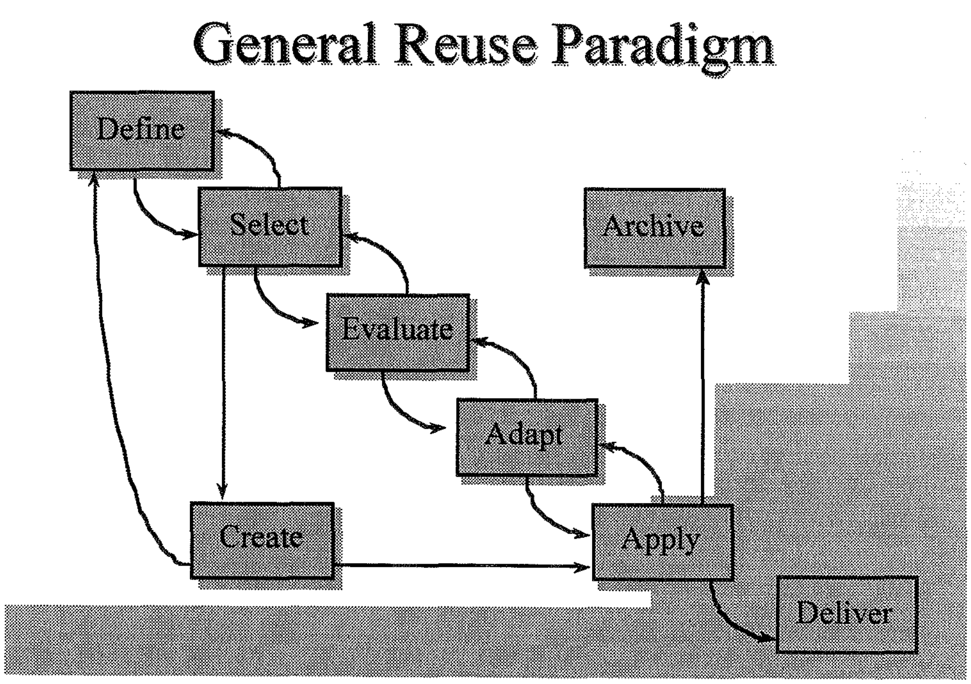
- Increase Quality
  - discover and correct deficiencies
  - refine objectives and structure
- Decrease Development Costs
  - Leverage off other related efforts
  - Avoid reinventing the wheel.
  - Optimize maintenance efforts.

General Paradigm for Reusability

One strategy that has been effective in other domains in both decreasing developmental costs and increasing quality involves the reuse of pre-packaged components. In much the same way as the "peer-review" process improves the quality of academic publications, reusing educational content would allow the collaborative efforts of a particular field's best educators to be brought to bear on the quality of every presentation. Lesson development time would also be reduced because of the existence of a peer-reviewed repository of educational resources from which to draw. The process of reuse can be generalized into the following steps:

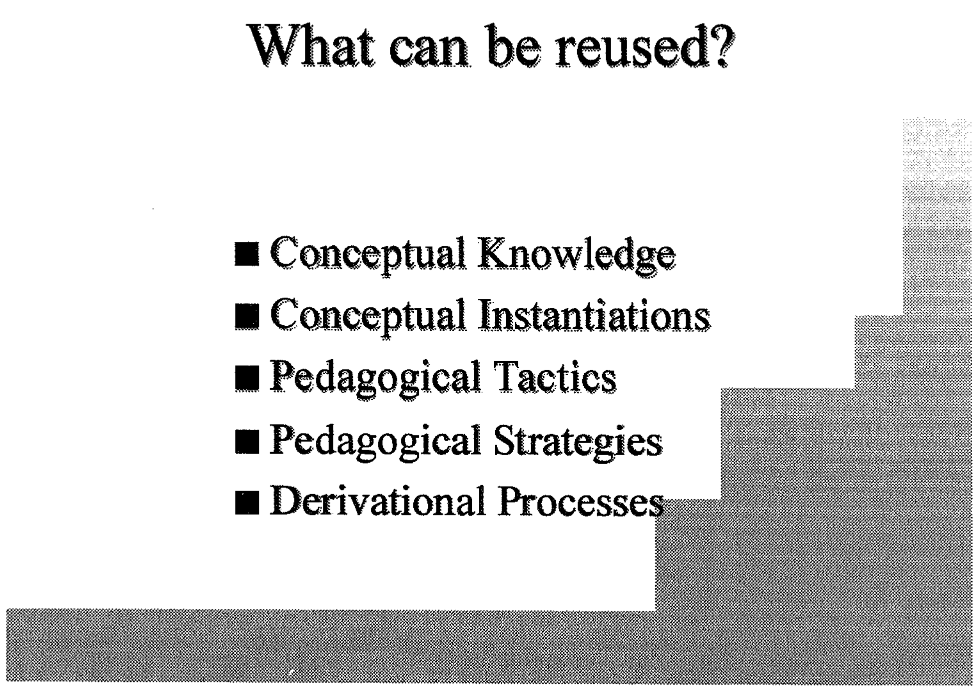
1. Identify and define requirements
1. Select a set of candidate resources from the repository
1. Evaluate each resource against the requirements
1. Adapt the closest match to fit the current requirements
1. Apply the changes to create a resource that exactly meets the requirements
1. Deliver the resources to the student

If no resources resemble the resource required by the requirements, then the resource must be developed "from scratch." In either case, once a resource is developed that is significantly different from those already contained in the repository, it should be added to the repository for future reuse.



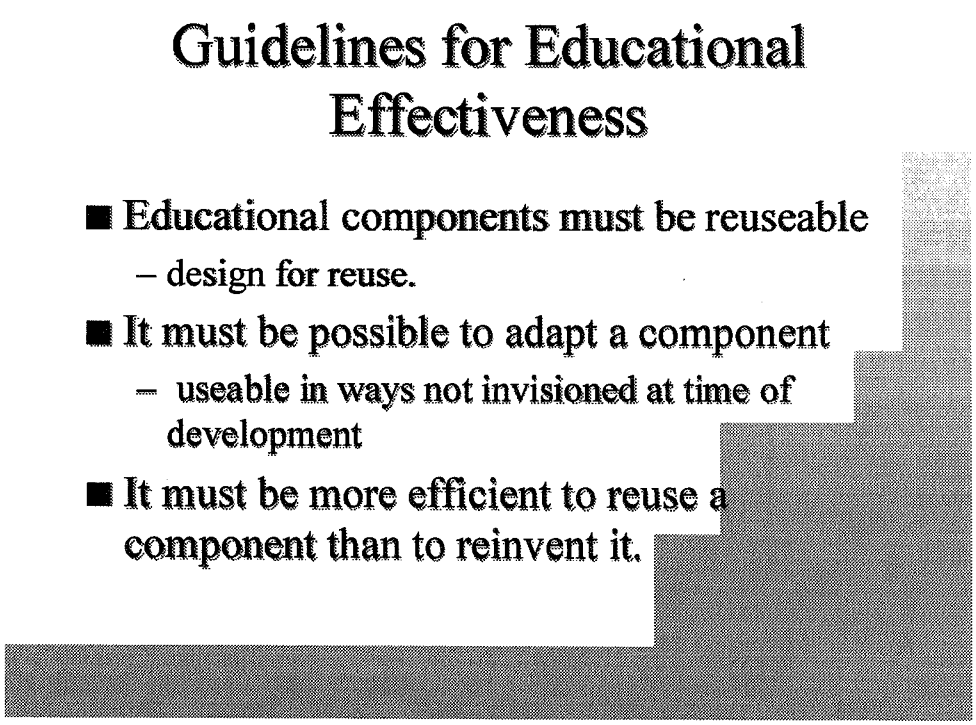
Reusable Educational Content

With respect to education, it is appropriate to ask the question: "What educational resources might be appropriate for reuse?" In general, educational artifacts that may be suitable for reuse include conceptual knowledge, conceptual instantiations, pedagogical tactics, pedagogical strategies, and elements of the derivational process. Conceptual knowledge consists of the key definitions, relationships, and processes that define a given area of study. Conceptual instantiations are examples that are particularly illustrative of a given piece of conceptual knowledge. Pedagogical tactics can informally be thought of as the "bag of tools" that educators use in communicating conceptual knowledge to students. Pedagogical strategies involve the global structuring of educational content necessary to successfully expose the relationships and dependencies between the concepts. Finally, with respect to educational content, elements of the derivational process itself (i.e., the steps followed in the development of educational content) may be reusable, particularly with respect to the adaptation of educational content to meet unanticipated requirements.



Lessons Learned From Successful Reuse Environments

A study of environments where reuse is an effective part of the design and development processes (such as digital circuit design) indicates that successful reuse is rarely an accident. In order for any artifact to be reusable, certain conditions must be met. First, it must be possible to gather artifacts into some central point for storage and retrieval (usually referred to as a *repository*) and to evaluate those artifacts against a set of criteria that is predictive of the successful application of the artifacts for some particular purpose. In order for that to happen, the **artifacts must be intentionally designed to support reuse**. Second, it must be possible to adapt the artifacts to fit requirements that are similar to, but not the same as, the artifacts' original intended purpose. Adaptation is facilitated by structuring artifacts such that **components are self-contained and focused**. Finally, in order for the process of reuse to gain acceptance among the designers and developers of artifacts, it must be more effective to reuse existing artifacts than create artifacts from scratch. To accomplish this goal, **tools and techniques must be developed to aid in the use of the repository**. Therefore, if we are to realize the benefits of reuse in education, we must find a way to package educational content and develop tools and techniques that allow educational content to be stored and retrieved, evaluated against certain criteria, and adapted for unanticipated purposes.



Dynamic Asynchronous Network Delivery of Individualized Education

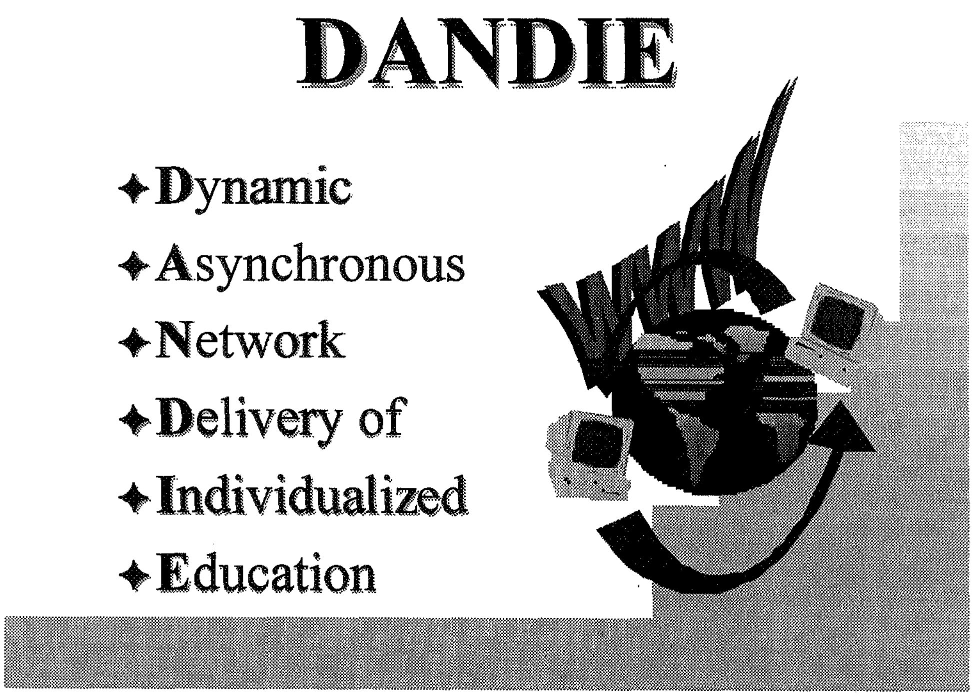
The Dynamic Asynchronous Network Delivery of Individualized Education (DANDIE) project seeks to develop the capability to augment conventional instructional approaches with computer-based instruction that is both responsive to the needs of individual students and cost-effective to produce and maintain. The elements of the project name identify key qualities that define the proposed solution:

Dynamic. Rather than storing "canned" presentations as is currently done, DANDIE seeks to represent core concepts in a presentation neutral form. Concepts are selected from the repository on an "as-needed" basis. Therefore, as the repository is updated, those changes instantly and automatically propagate to all students.

Asynchronous. Delivery of educational content over the Internet on demand allows the individual student to access the system at his/her own convenience. Education is no longer limited to prescheduled class meetings.

Network Delivery. By utilizing technology recently developed for the Internet (e.g., the HTML language, world-wide web (www) servers, browsers, Java applets, etc.), the ability to distribute instruction is no longer limited by geographical proximity.

Individualized Education. By dynamically generating lessons from conceptual knowledge, the presentation can be structured in such a way as to facilitate the learning of individual students.



Specific Project Goals

The specific goals of the DANDIE project are to increase the quality and availability of computer-based instruction while reducing the investment required to produce such instruction. The project is structured into two primary thrusts: one involves research into the efficient population of the knowledge base with course specific knowledge and meta-knowledge; the other involves the retrieval, organization, and presentation of this knowledge in such a way that facilitates the learning of individual students.

GOALS

- Effectively elicit knowledge
- Improve the quality of education
- Minimize resources consumption
- Maximize Educational Reuse
- Individualize instruction

The University of the Future

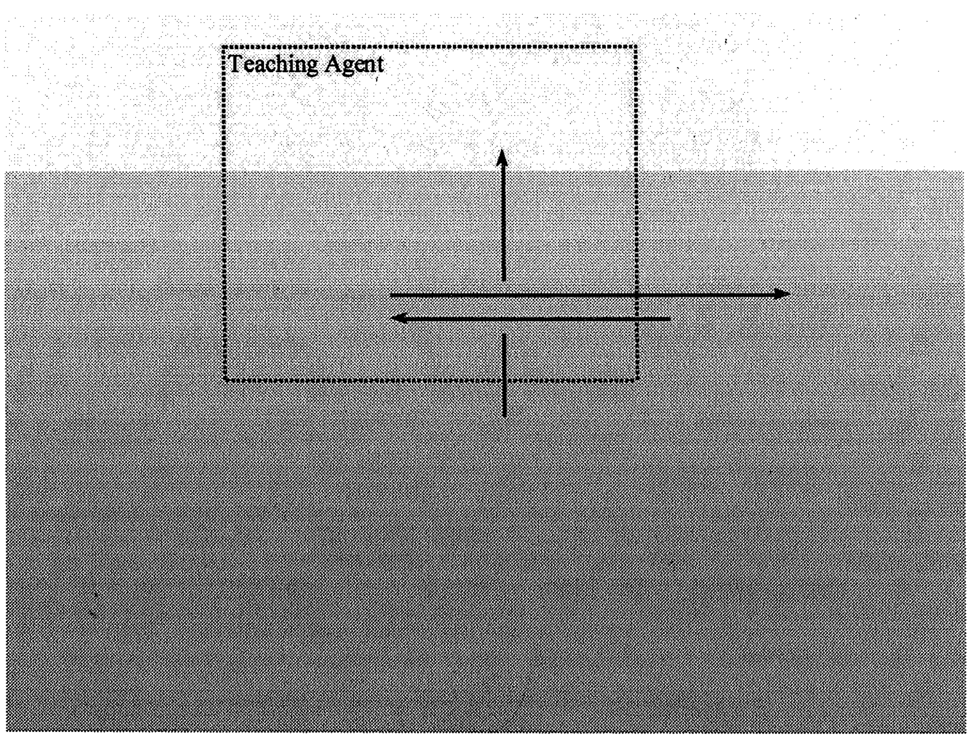
We envision the type of capabilities that the DANDIE project is seeking to produce to be only one element of the virtual university campus of the future. In order to facilitate learning, opportunities for interaction with instructors and with other students must be supported, both through conventional mechanisms (such as class meetings, help sections, discussion groups, etc.) and through electronic communication mechanisms. The division of labor between an automated instructional system and a human instructor should be structured to take advantage of what each does best; the human instructor is best at motivating, inspiring, and encouraging learning, while the instructional system is best at storing and retrieving core conceptual knowledge. Thus, we would advocate a model of instruction in which students are organized into conventional classes, but those classes would meet less often (perhaps only weekly). These meetings would be primarily for the purpose of giving the instructor an opportunity to motivate the topics and reinforce key concepts. The bulk of the knowledge transfer would occur at the student's convenience through interaction with the on-line instructional system.

System Context

- One component of the Virtual Campus
- Exists in tandem with electronically enhanced communications environment
  - Asynchronous Communication
    - » email, newsgroups, webboards, static web pages
  - Synchronous Communications
    - » chat, netphone, collaboration support

System Architecture

The architecture for the DANDIE system revolves around two main knowledge bases: the Domain Knowledge Model which contains the conceptual knowledge from the domain of study, while the Student Knowledge Model records information about each individual student. The educator acts in the role of Human Expert, and interacts with a Knowledge Elicitation Agent to populate the Domain Knowledge Model with the conceptual knowledge. A Structure Agent is responsible for strategic decisions involving what set of concepts should be presented to the student. A Presentation Agent is responsible for tactical decisions involving how concepts should be presented. Both the Structure Agent and the Presentation Agent interact with the Student Knowledge Model in making these decisions. The Student Performance Agent is responsible for interacting with the student and in evaluating the effectiveness of the learning process. Information regarding student progress is also stored in the Student Knowledge Model. Finally, the System Performance Agent is responsible for assessing the effectiveness of the decisions made by the Structure Agent and the Presentation Agent with respect to student performance.



Effective Knowledge Elicitation

The goal of the Knowledge Elicitation Agent is to facilitate the transfer of domain knowledge from the human expert (educator) to the knowledge base (repository). Experience suggests that there is as much as a 200:1 ratio of investment to presentation time in the development of conventional computer-aided instruction. This is obviously too great a burden for most educators to bear and seriously prohibits the acceptance of computer-augmented education as a viable strategy. Therefore, the effective operation of the Knowledge Elicitation Agent is of critical importance to the success of DANDIE. The Knowledge Elicitation Agent fills the role of knowledge engineer in conventional expert system design. As such, it must encapsulate knowledge about the representation used by the knowledge base, common (or primitive) domain vocabulary and relationships, and must encode mechanisms for mapping between the two.

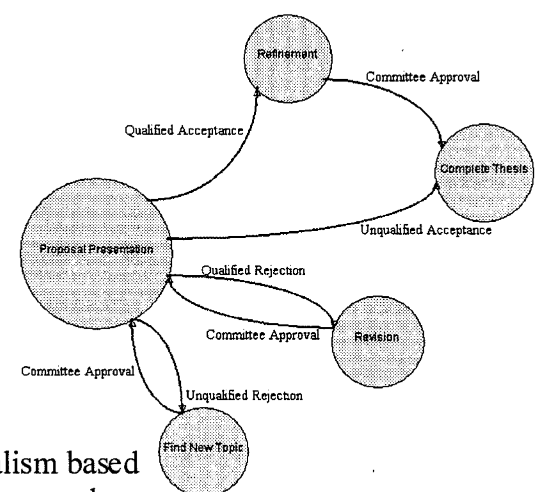
Knowledge Acquisition

- **Goal**
  - Capture domain knowledge in an electronic knowledge base
- **Knowledge Engineer**
  - Conversant in knowledge domain
  - Experienced with knowledge base

Knowel: Knowledge Elicitation Tool

KnowEl (Knowledge Elicitation) is a prototype tool under development as part of the DANDIE system that allows the educator to specify procedural and declarative process knowledge in a graphical format for transfer to the DANDIE domain knowledge base. KnowEl is based on an extension of the state-machine formalism, and translates its graphical notation into first-order logic formalism based on the situational calculus. In addition to eliciting knowledge, KnowEl is also capable of analyzing the resulting logical formulae for consistency.

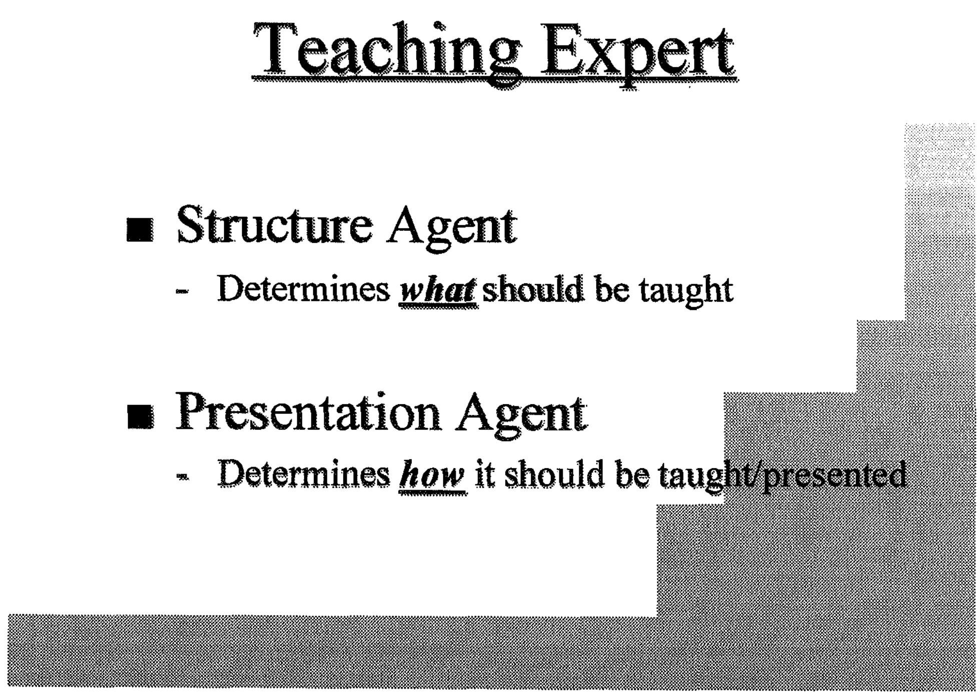
KnowEl -
Procedural
Knowledge
Elicitation



1st-order formalism based on category theory and situational calculus

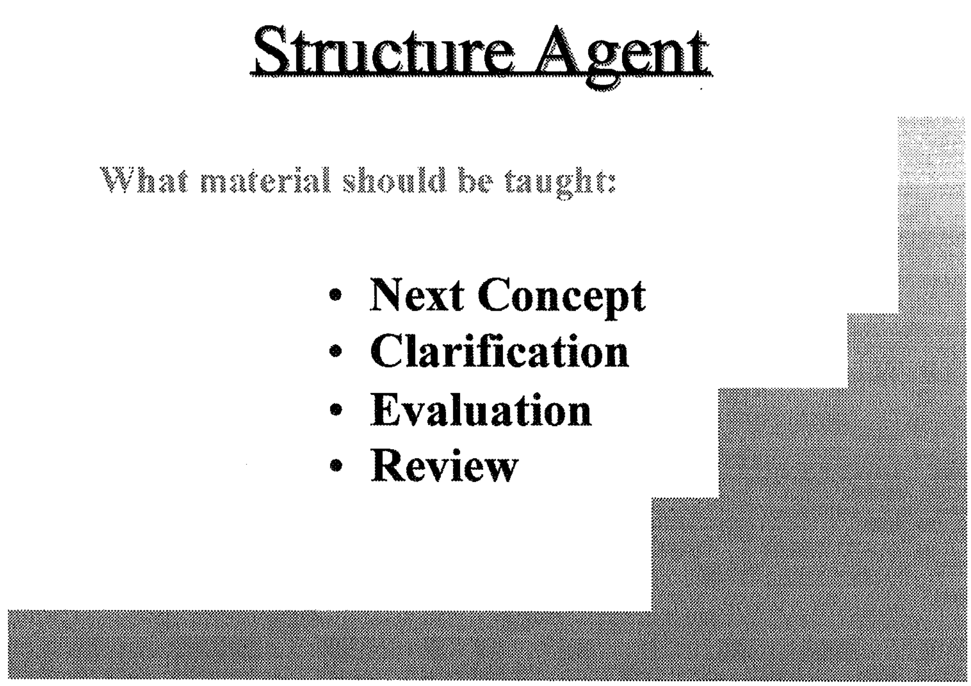
Effective Teaching

The heart of the DANDIE system is the teaching module. The teaching module is divided into two major components: the Structure Agent and the Presentation Agent. The Structure Agent determines what should be taught. Creating a plan that considers the goals of the instruction, the inherent structure and inter-dependencies of the domain knowledge, and the individual learning style of the student does this. The Presentation Agent is responsible for determining how a particular conceptual knowledge component should be taught. In making this decision, the Presentation Agent must choose a presentation style and tactic based upon the characteristics of the knowledge component and the preferences (both stated and observed) of the student. In this manner, effective teaching is accomplished by creating a flow of information that is uniquely oriented to meeting the needs of the individual.



Student-Specific Educational Structure

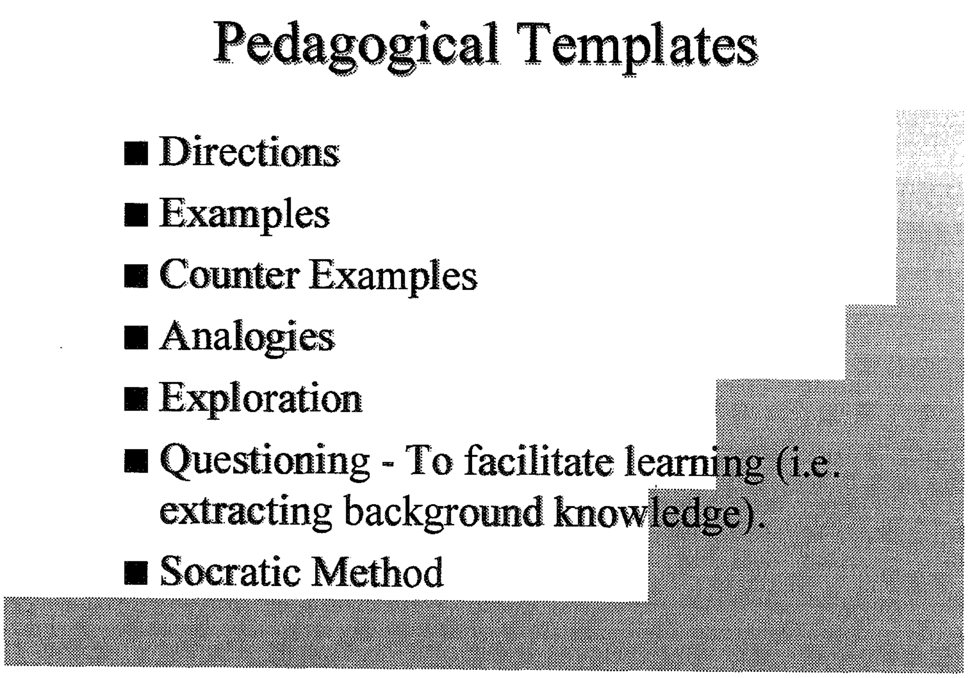
In making decisions about what should be presented next, the Structure Agent must interact with the Student Knowledge Model. If there is evidence to suggest that the student has internalized the concepts in the current presentation, then the Structure Agent should select the next concept from the overall lesson plan in accordance with the structure of the domain knowledge. However, if there is evidence to suggest that the student has not internalized the present concept, then the Structure Agent may decide to present the concept again (informing the Presentation Agent to select a different pedagogical tactic), request further evaluation to attempt to identify the specific conceptual deficiency, or determine that a review of pre-requisite material is necessary to facilitate learning of the present concept.



Student-Specific Educational Templates

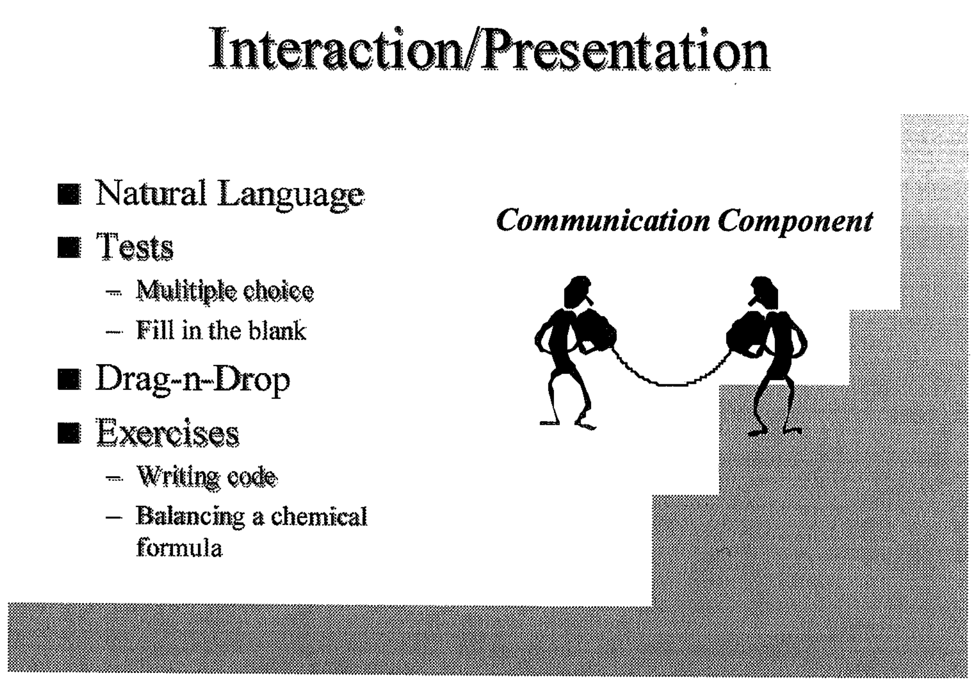
The Presentation Agent encodes a number of techniques for transforming conceptual components into an educational presentation. These are analogous to the set of techniques that an instructor might use while lecturing. These techniques include:

Directions. Presenting a linear description of a set of (usually temporally) related concepts.
Abstractions. Presenting an abstract view of a concept and requiring the student to apply the abstraction to the current topic.
Examples. Presenting a set of specific instances or situations and requiring the student to generalize to find the abstraction.
Analogies. Presenting an unfamiliar concept in terms of a previously mastered concept with similar structure.
Explorations. Presenting scenarios and requiring the student to project outcomes.



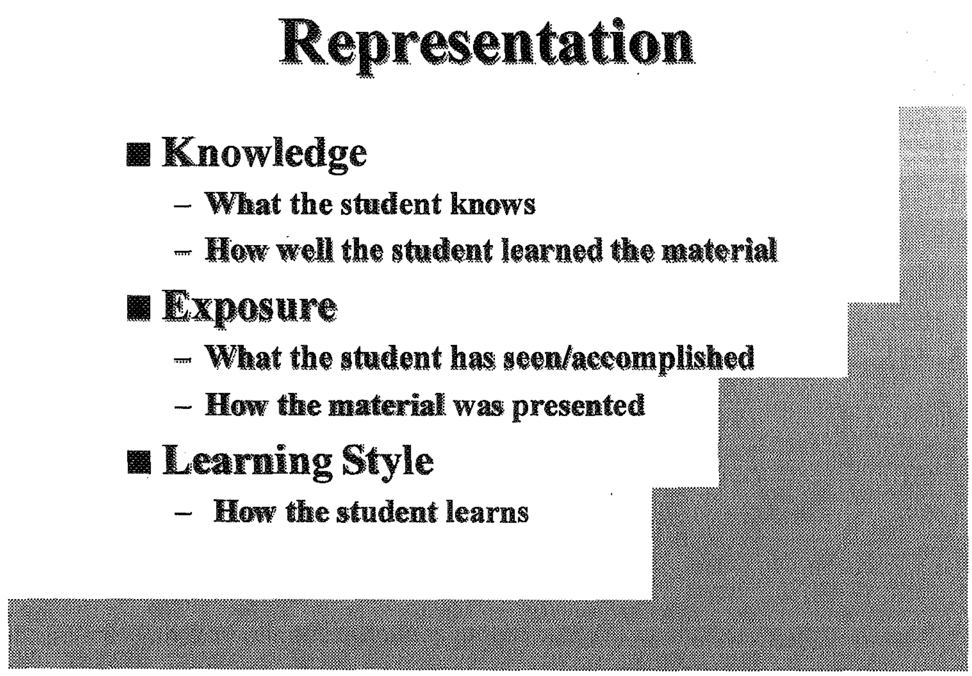
Presentation Format

The current target format for the Presentation Agent is the HyperText Markup Language (HTML) supported by common web browsers. The content of each dynamically generated web page consists of structural information (headings, lists, tables, etc.), English text generated from the application of one of the pedagogical tactics to a concept knowledge component, and interactive form elements (radio buttons, choose boxes, and text fields) to support student evaluation. As research progresses, support for multimedia components will be added to the system and included in the target presentation format.



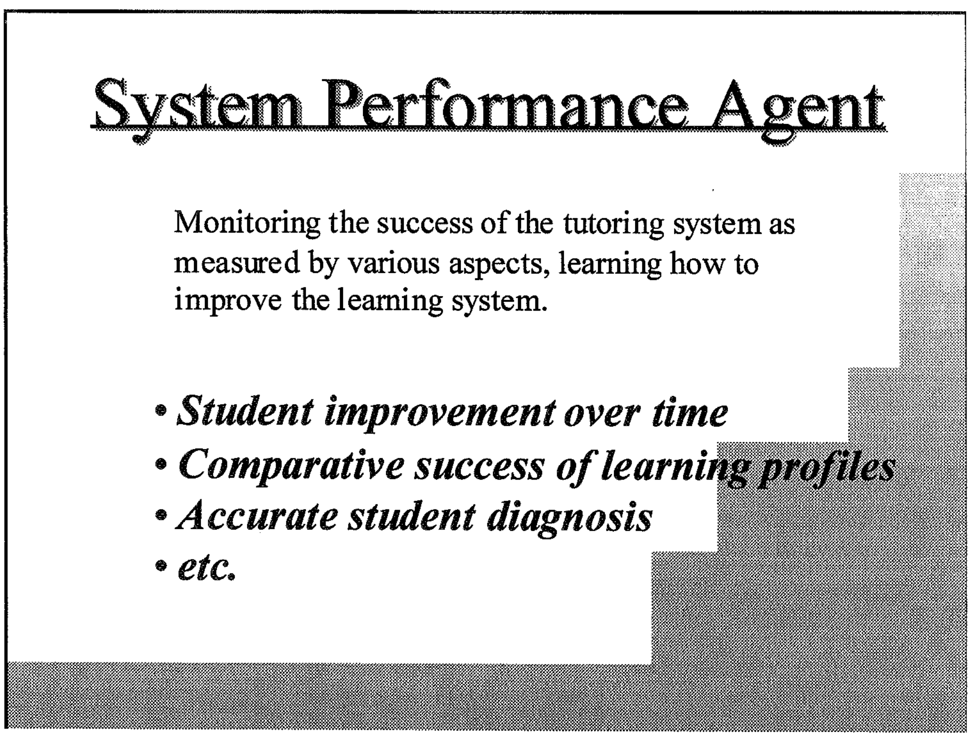
Student Evaluation Agent

The Student Evaluation Agent is responsible for monitoring student responses to presentation content and recording student information in the Student Knowledge Model. The information recorded by the Student Evaluation Agent relates to what knowledge the student has mastered in the past, what the student has been exposed to in the current session, and how effective various combinations of strategic and tactical presentation decisions have been for facilitating the learning of this student. Knowledge about the student's past learning includes conceptual knowledge the student studies and how well the student did at mastering those concepts. Knowledge about the current session includes what concepts have been presented, and what combinations of presentation decisions were made in presenting the material. Knowledge about the student's learning style relates to the effectiveness of these various presentation decisions.



System Performance Agent

The job of the System Performance Agent is to monitor the overall effectiveness of the strategic and tactical knowledge encoded in the system. This information is then used to dynamically bias the starting state of the system for new students to favor those strategies and tactics that have been most successful in the past. This information is also useful to the system developers and maintainers in identifying areas for future research, improvement, and repair.



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Advancing the Technology Teaching Front

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Advancing the Technology Teaching Front

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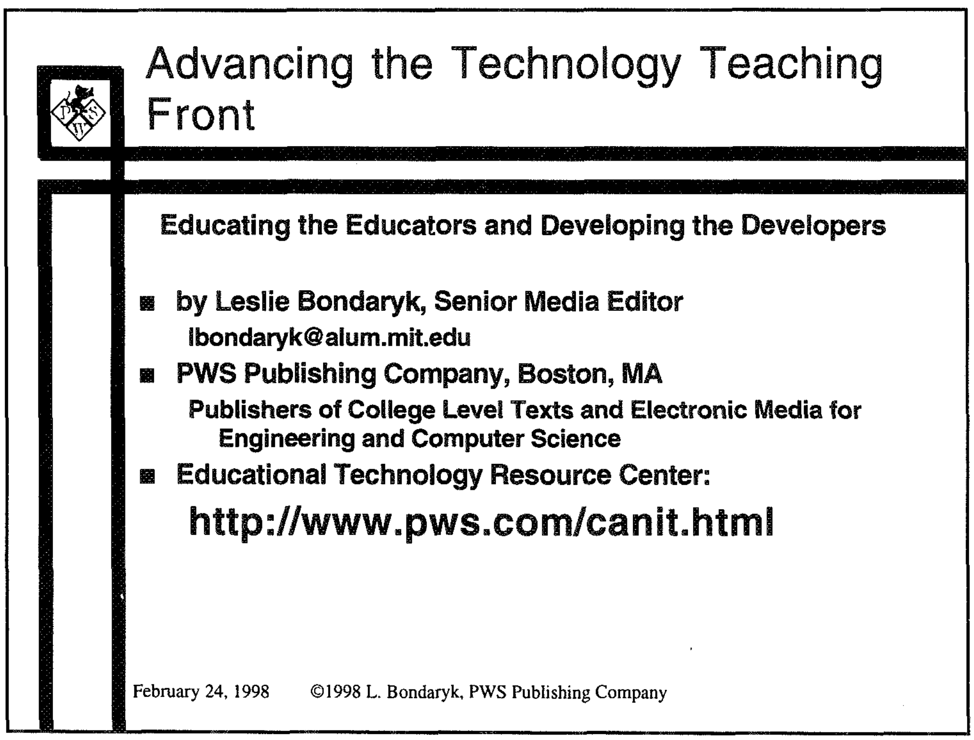
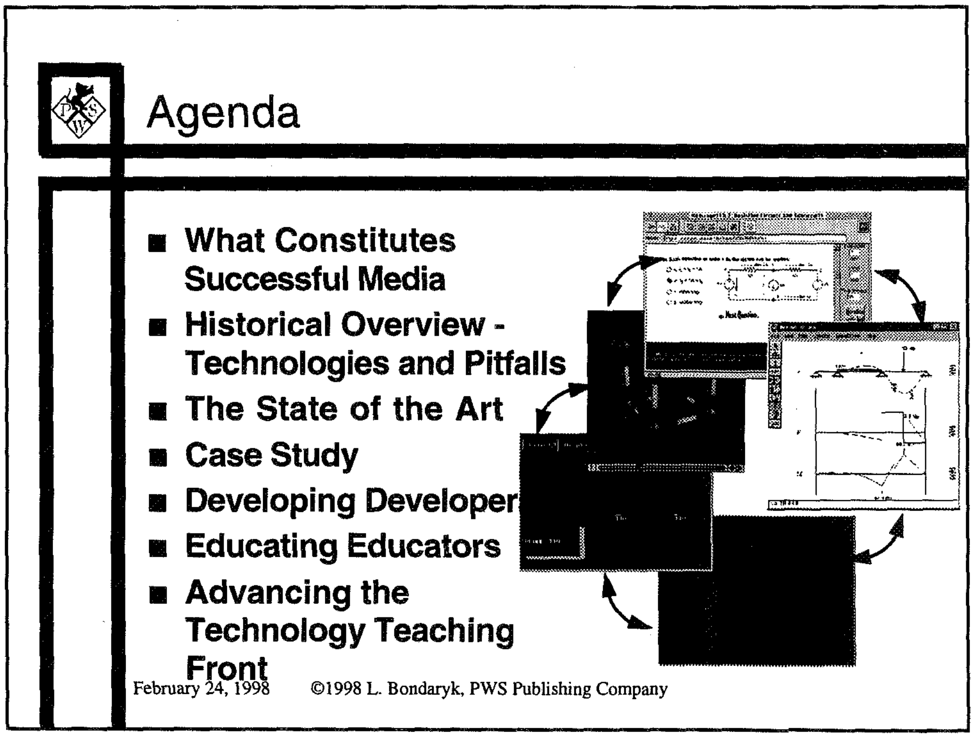
My name is Leslie Bondaryk and I am the Senior Media Editor at PWS Publishing, which means that I work with authors and educators who write and teach with software. PWS Publishing specializes in engineering and computer science educational materials, which prompted me to begin an on-line listing of all new media products in these areas that I came across. Let me give a little plug for this resource: this listing helps me to see at a glance what is going on in the area of new media development, and hopefully will help you to find out what is being developed as well. If you are looking for software in engineering education, please visit the center, and if you are developing some, please drop me a line so I can include your contribution. Everything can be found on-line at

http://www.pws.com/canit.html



Agenda

Software for engineering education has undergone some dramatic changes in the last years, but you know what they say - the more things change, the more they stay the same. There was electronic multiple-choice testing in the DOS era, and now it's back again on the Web. There were numerical solvers then and now, and there were programs that helped instructors to keep grades and evaluate class performance then and now. The difference is that we have learned some lessons in the last three operating systems, and have started to listen to our colleagues in education and our students. We have also started to take advantage of the powerful new machines that sit on every desktop to bring things to life visually, to ask more interesting questions, and to let the student be more self-directed. It is worth examining why some things that went before failed, so we can teach ourselves to become better authors of interactive media, and make media effective for the students. How can we educate our colleagues at the same time as we deliver modern media into the classrooms? What can we do to help each other?



Defining Successful Media

My premise is that successful media is widely applicable in the community. Currently, engineering educational materials are still chosen by the instructor, specified to the bookstore, and bought (for the most part) by the students. So it's still the instructor you have to convince that media is worthwhile. Successful media must be recognizable as effective to the majority of engineering faculty worldwide. It either has to fit in with their current model of teaching, or provide clear guidelines about how the teaching model must change, and compelling arguments about why it should change. It's clear that interactive media will eventually necessitate a change in teaching style, at the very least from asking what the answer is, to asking what the answer means. The reviews we conduct are a relatively effective measure of whether the message is getting across, and qualitative acceptance generally leads to quantitative evidence: requests, downloads, or sales numbers. This may seem somewhat mercenary, but sales are the most important feedback mechanism the community has to tell publishers whether they are doing a good job, and are therefore a reasonable good metric of a successful product.

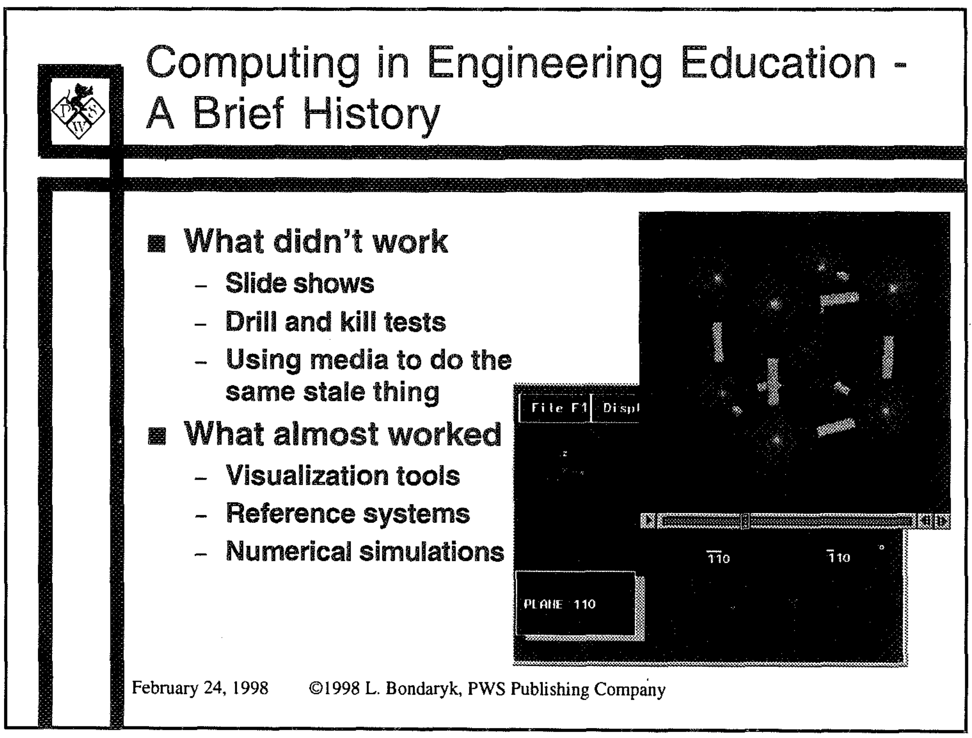
Defining Successful Media

- **Qualitative**
  - **Effective for education**
  - **Superior to paper**
  - **Easy for students to use**
  - **Easy for instructors to use**
  - **Reviews/shows well**
- **Quantitative**
  - **Carries a demonstrable positive reputation**
  - **Frequent requests/downloads of product or demo**
  - **If published, sales quantities should be high**

February 24, 1998

Computing in Engineering Education - History

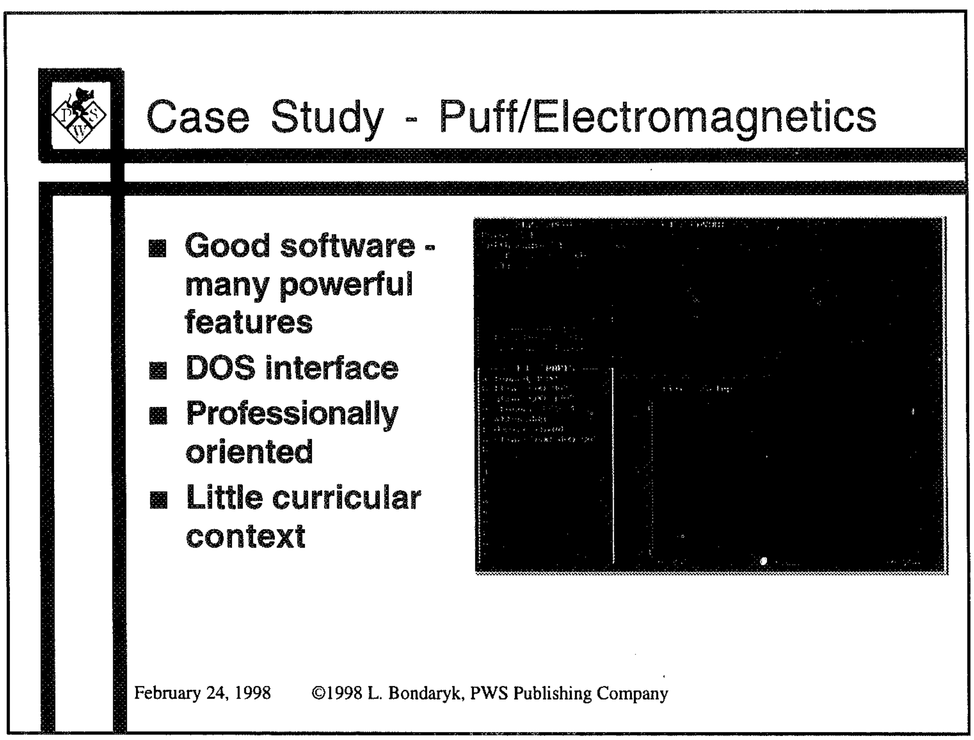
Armed with qualitative and quantitative measures, let's ask what worked, and what didn't? Most of us are familiar with the drill and kill tests that were ubiquitous in the DOS age. These were of limited value because they didn't give qualitative feedback to the student. There were also books on screen, such as the infamous Anton Calculus CD, that did not let the student do more than click a forward button in the name of interactivity. Many of the first forays into media arts tried to bring to life old, stale methods, but all you get that way is something stale that rotates. Other projects weren't very successful that probably should have been, and it's worth examining why. Visualizations are useful whenever describing complex multidimensional or time-varying objects; movies such as those made by John Russ for Materials studies, or electromagnetic animations from CAEME at the University of Utah were, and are, useful tools for the lecture environment. These carry the weight of widespread recognition, but never succeeded wildly as published media. There were also a variety of table lookup programs such as ALLPROPS Thermodynamics Software from the University of Idaho, and some very credible DOS numerical simulators, which are of clear benefit to engineering studies. So why didn't these succeed?



Case Study - Puff/Electromagnetics

The visualization, reference and numerical simulation tools really should have been a success. They allow students to do more interesting problems than can be done on paper, and allow them to begin thinking about the big picture, instead of the number crunching. To demonstrate, here is a screen from a 1991 program for doing microwave circuit analysis, Puff, by Wedge, Compton and Rutlege, professors from Caltech and Cornell. It is a powerful program, allowing the user to draw transmission lines, and simulate the time-domain (steady state or impulse response) and Smith Chart characteristics of the circuits. So why wasn't every engineering college using it to teach Smith Chart Analysis?

At first, many universities didn't have the computer facilities, and instructors were not sufficiently comfortable with the technology. Also, the program is hard to use. It uses a keyboard interface, and takes an expert's view of the problem: it assumes that the student knows how and why to solve transmission line problems, leaving them bewildered if they don't. It does not take a pedagogical viewpoint. Finally, there are only the briefest of notes in the user's guide showing how it relates to the curriculum. There is no contextual framework for it.



What Held Us Back?

Lack of recognition for worthwhile educational software results in large part from a lack of curriculum guides or references to established textbooks/syllabi. We have frequently found that software is more readily - and sometimes only - adopted when there are obvious links from software to print. A majority of instructors still use texts, so a bridge must be provided from the old to the new, or a guide for converting to a new system of teaching. I don't mean to oversimplify the problem. There are many factors that keep technology out of the classroom. Faculty are time-sensitive, so they don't figure out how to integrate software into their classrooms, or reinvent their classrooms, particularly if the department doesn't support these efforts. They are stymied by lack of equipment and personnel. Early software offerings from textbook publishers showed our inexperience in producing it, leading to bad experiences for early adopters. Some instructors even fear that they will be replaced by the computer, or that their students will understand the new software tools better than they do, or that software developed by someone else won't work in their version of the syllabus. It behooves us, as developers of educational media, to pay as much attention to these support issues as we do to developing the software itself.

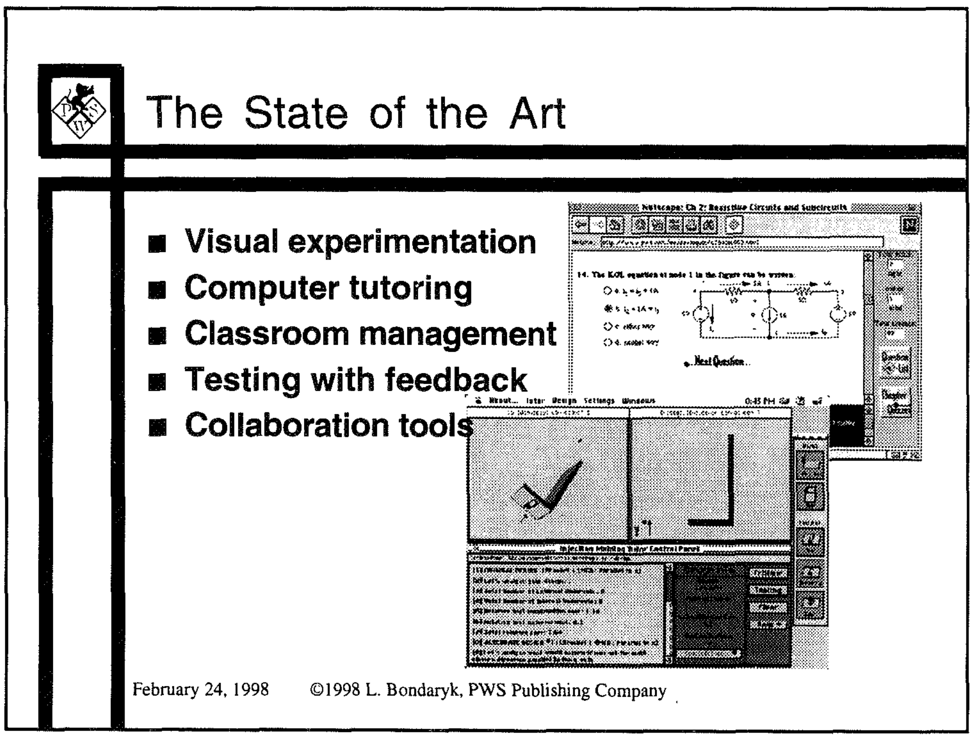
What Held Us Back?

- **Practical Limits**
  - **Time and Political constraints**
  - **Technology constraints**
- **Publisher's Inexperience**
  - **Insufficient bug testing**
  - **Unprofessional design**
- **Emotional Limits**
  - **Not-grown-here syndrome**
  - **Multimedia dread**
  - **Fear of obsolescence**

February 24, 1998

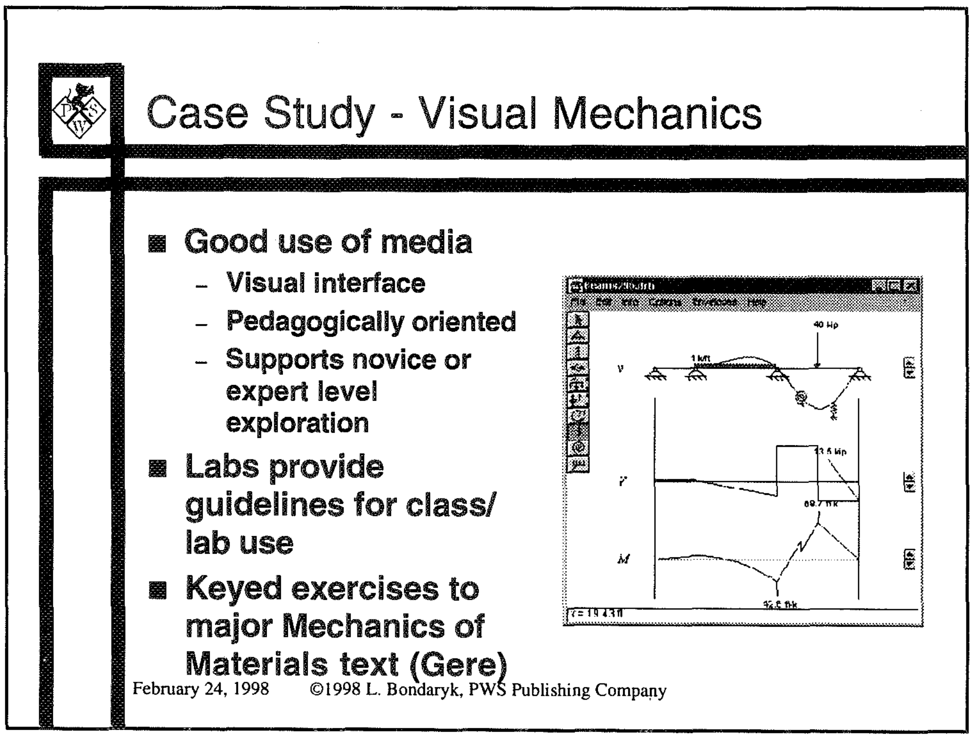
The State of the Art

Where are we now? Increased computing power makes possible more sophisticated kinds of software: visual simulators replace raw mathematics and keystrokes. We can focus on helping students take the conceptual leap between the math and the physics. The materials you saw earlier today from Don Millard's group at RPI are examples of this type of system. As our collective experience in interface design and authoring systems grows, we can produce tools that allow students to not only experiment, but also to get feedback on their progress. The tutoring systems you will see tomorrow from Beverly Woolf from the University of Massachusetts help a student to follow the correct solution path by demonstrating the results of errors, and tracking when those errors occur. Course management tools are being reinvented for the Web under the heading of distance education, and virtual spaces and exercises that encourage student collaboration are emerging, like CyberProf from Alfred Hubler, or the University of Mississippi system set up by Pamela Lawhead. But while these tools have gotten more satisfying and sophisticated, and while administrators are more supportive, we still need to overcome the emotional residue of previous experience and the fear and loathing of switching teaching techniques.



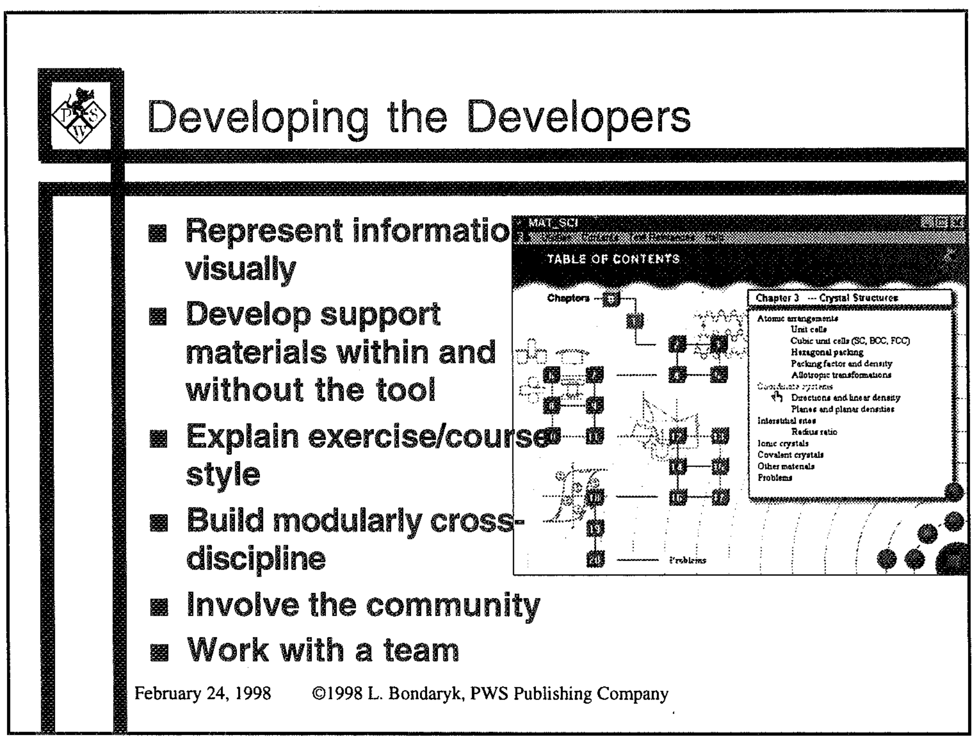
Case Study - Visual Mechanics

Here is an example of a tool that does seem to be succeeding in the current adoption environment. Greg Miller and Stephen Cooper from the University of Washington created a series of beam analysis tutors called *Visual Mechanics*, which have a sophisticated finite element simulator underneath, but show the visual metrics of a problem at the topmost level. The software is easy to use - loads, moments, and supports are dragged and dropped onto the beam, and the displacement, shear, and moment graphs update in real time. The graphics all relate directly to the iconographic shorthand used by engineers. Limited testing with students shows that the students are getting slightly better grades, and course ratings have improved. Faced with the challenge of enabling the community to use these tools without having the developers teach the class, I recommended that a lab book be created to go with the software. The exercises are simple, with the expectation that the instructor will invent more as they get comfortable with the software. The print lab book is a starting point for evaluating and applying the tools. Introduced one semester ago, *Visual Mechanics* has sold 720 copies. This is unheard-of success in the first year of a new-media engineering product, and bodes well for future success of this and related products.



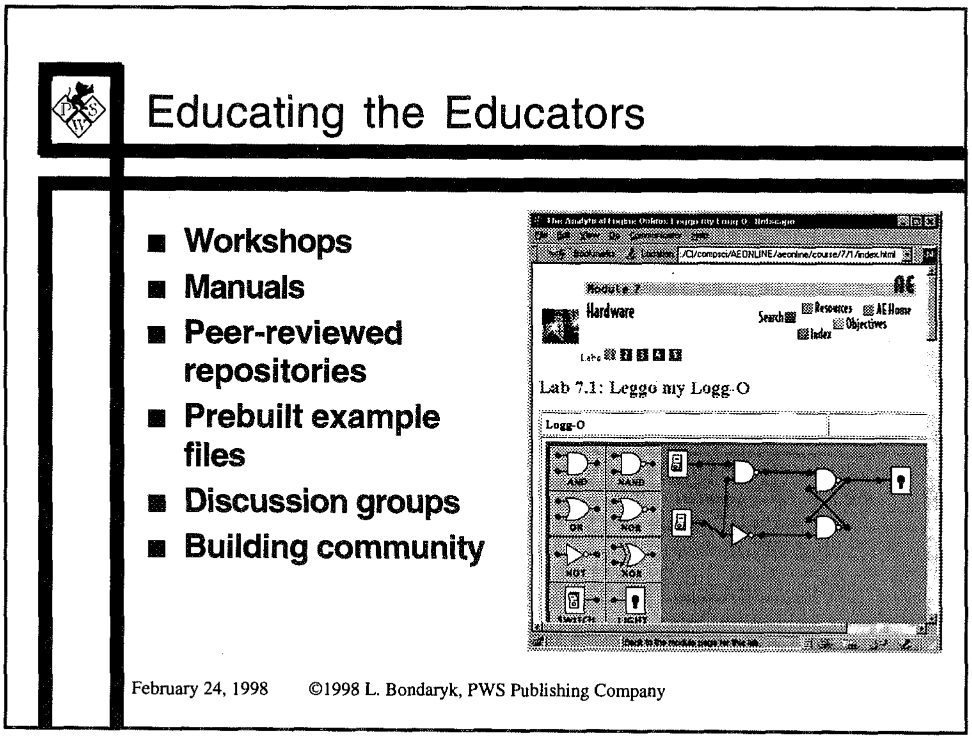
Developing the Developers

To get the most out of new media tools and ideas, developers and distributors need to create guidelines for use. Visual and/or textual views that show the domain covered by the tool, and how it will be covered, can be done in the interface, as shown here in the Russ CD "screen of contents," or in a print guide, such as the lab book accompanying *Visual Mechanics*. Connections should be demonstrated to print or other existing teaching tools, using page references, if appropriate, or a guidebook to show how the software takes a totally different approach. Always relate back to the familiar. Use authoring styles and tools that allow flexibility and customization. Let instructors choose the pieces that suit them, encouraging them to try additional pieces in the future. This approach makes projects more extensible as well, allowing the addition of new concepts within a consistent model. This is valuable to both the developer and the adopting school - it is much easier to keep teaching or developing with a consistent model than to switch models every semester. Stressing accessibility may also help developers to make better use of the media. Clarifying the educational approach used within the software will force a definition of goals in these areas.



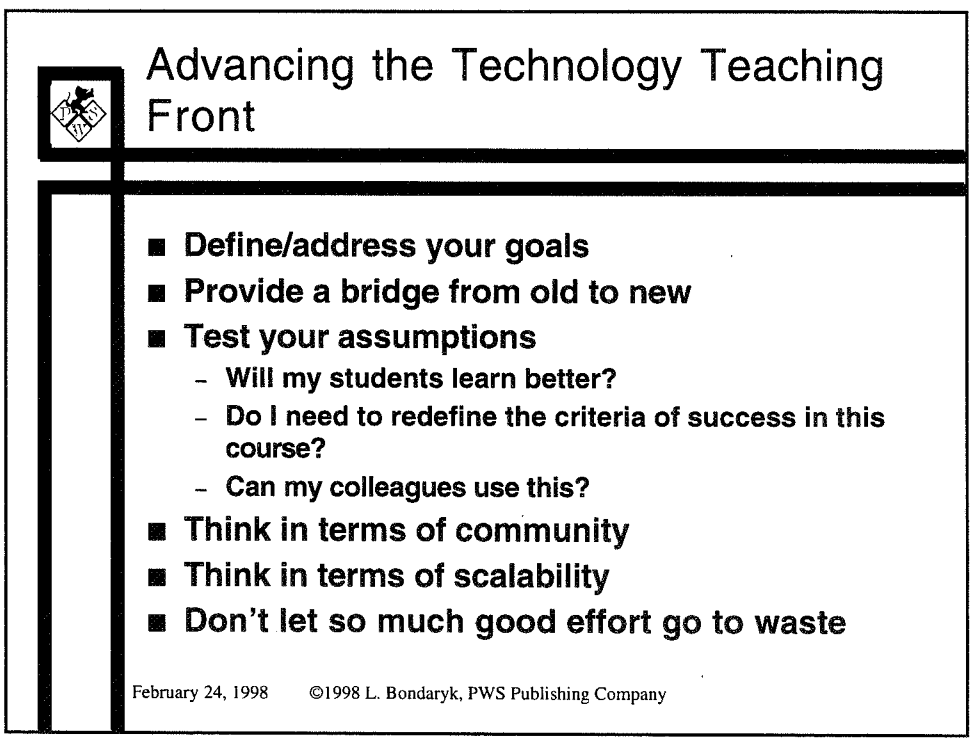
Educating the Educators

New media authors and publishers are developing a new relationship with the instructors who use their products. Accessibility tools (lab books, interface, on-line help) can be accompanied by more proactive measures, such as workshops, academic paper presentations, peer-reviewed repositories and on-line discussion groups. For example, we are currently operating a growing email discussion group for users of an introductory computer science project called the *Analytical Engine On-line (AE)*. This group allows instructors with a very broad international and institutional demographic to exchange ideas for using AE, and also allows them to talk to the authors. This helps them to feel less alone in whatever issues they have using the materials, and helps us improve the accessibility of materials in future editions. Web resource centers, like the one I mentioned at the start of this talk, and the NEEDS database that Brandon Muramatsu hosts, help to educate about the available types of tools. Community involvement is perhaps the most important feature for any system that educates the educator. The ability to hear what other instructors think is critical to the acceptance and use of new tools. It is very important for them to have a support network and a feedback path while they are trying new tools and teaching styles.



Advancing the Technology Teaching Front

To succeed in introducing technology to engineering education, and thereby transform it into something more effective, we must plan carefully the type of media we develop. The project must address some presently unfulfilled need in the educational community, whether that be for testing, presentation, curriculum flexibility, or novel concept exploration. In addition, these projects must be applicable outside the author's classroom. Development plans must include specific methods for instructors and students to use the materials, and will support learning methodology as well as engineering content. New media ultimately implies some rather dramatic changes in the way we teach, and it is our responsibility as developers to help our colleagues feel comfortable with the new paradigms. Recall that our presented internetworked state makes it very easy to talk to each other about what we are doing - take advantage of it. Through your own resources, or those of a professional publisher, maintain an ongoing dialog with the community of users. Finally, we must begin to develop for the program, rather than for the course, since there is a strong desire on the part of the academic community to stick with a unified technology system. I strongly recommend the development of modular systems that can grow with the instructors who use them.



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NEEDS: The National Engineering Education Delivery System

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NEEDS

The National Engineering Education Delivery System

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NEEDS

The National Engineering Education Delivery System

Workshop on
Advanced Technology
for Engineering Education and Training
February 24-25, 1998

Brandon Muramatsu
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February 24-25, 1998

Outline

Below find the outline for the talk.

Outline

- Questions . . .
- Brief History
- What is NEEDS?
- Reviews of Courseware
- Into the Future . . .

February 24-25, 1998

Brief History of NEEDS

NEEDS — The National Engineering Education Delivery System — is the distributed architecture developed by Synthesis: A National Engineering Education Coalition to enable new pedagogical models based on Internet-mediated learning environment.

Brief History

- **Synthesis Coalition Established 1990**

  Synthesis Coalition Goals
  - **Reform curricula**
  - **Improve retention**
  - **Link to K-14**
  - **Develop digital infrastructure**

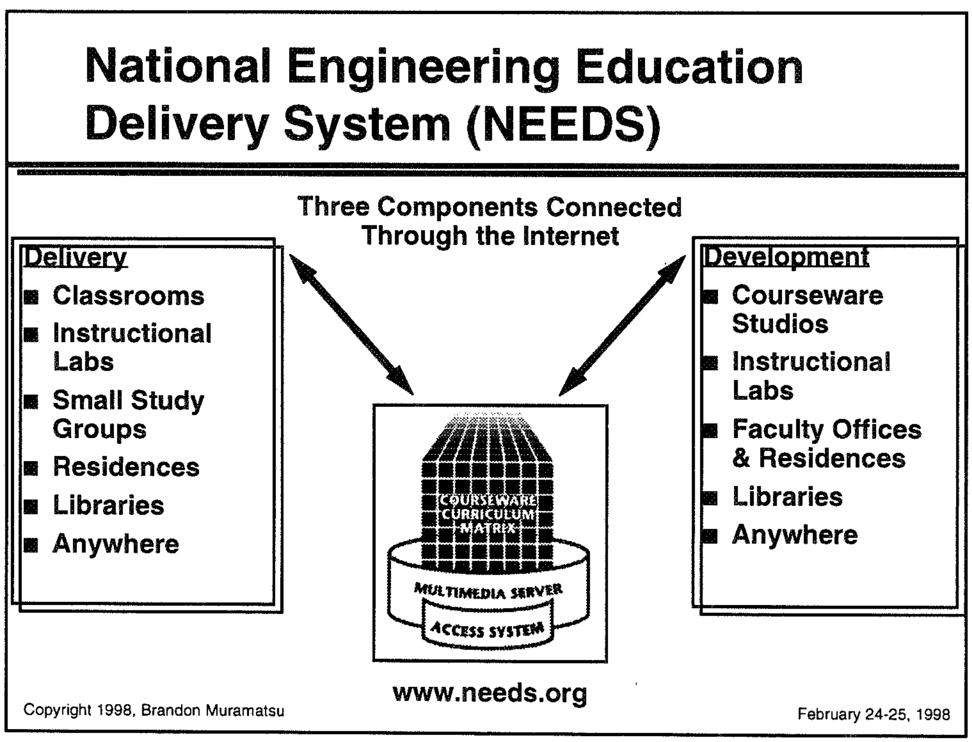
- **NEEDS is the digital infrastructure developed by Synthesis**

 February 24-25, 1998

NEEDS — Supporting Anywhere, Anytime Learning and Development

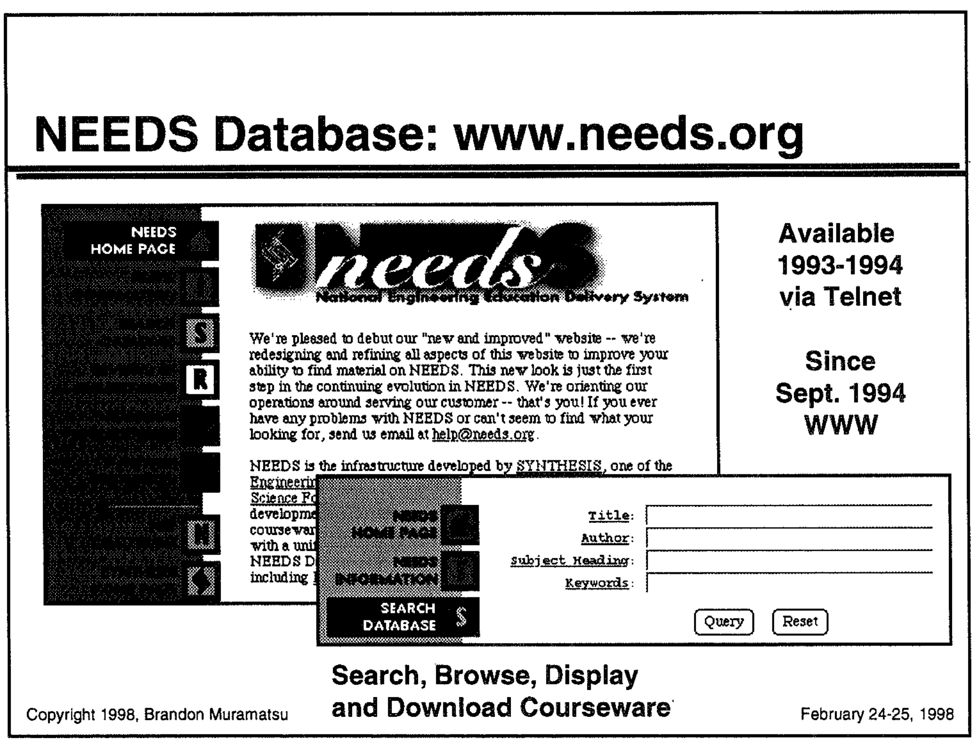
The emergence of the World Wide Web (WWW) in the mid-1990's as a viable means for national and international sharing and re-use of educational materials fundamentally changed our view of the way education and learning can be delivered. Internet-mediated learning environments provide mechanisms for the learner to be anyone, anywhere, at anytime. NEEDS catalogs courseware and other instructional technology being developed nationally and internationally to provide a resource where learners can search, access, and download materials to support their learning process.

NEEDS is three components connected through the Internet. The Development and Delivery of Instructional Technology are supported and made possible through a database or repository of engineering courseware and multimedia elements.



NEEDS is Available on the World Wide Web at www.needs.org

NEEDS can be searched for courseware and multimedia elements on the World Wide Web at www.needs.org.



Expanding NEEDS Services to Develop the Foundation for an On-Line Community

NEEDS has developed an infrastructure to address the needs of the engineering community by providing a widely accessible dissemination vehicle with an index and archives of courseware as well as a strong review and evaluation system for courseware. NEEDS has identified the development of a critical mass of content and viewership as two key factors in system success. The critical mass of content is key because it forms the basis around which we can develop additional services to form the on-line community. The success of NEEDS as a service depends not only on the development of a critical mass of content but also on the development of a critical mass of viewership (which is to say, building a community). The development of an on-line community provides the means of sustaining NEEDS as a service, by providing more than just an index of courseware. The services continually draw the user back by stimulating discussion among learners and developers, adoption and adaptation of existing courseware, new courseware development and courseware acquisition. Thus NEEDS becomes an actual Internet-mediated learning environment.

Below is a list of what the new services to support a user community might include.

Expanding NEEDS Services to develop the Foundation for an On-line Community

- User and Author Services
  - User reviews of courseware
  - On-line discussion
  - Adoption/adaptation usage statistics for the author
- NEEDS Services
  - Extended usage tracking
  - User registration and profiles

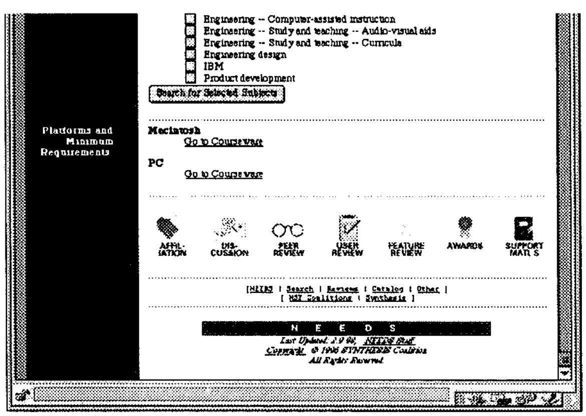
 February 24-25, 1998

New Services Available From Catalog Records

Many of the features of the on-line community will be directly accessed from the courseware catalog record.

Below is an example of what that catalog record might look like.

New Services Available From Catalog Records



- Affiliations
- Discussion
- Peer Review
- User Review
- Feature Review
- Awards
- Support Materials

February 24-25, 1998

Evolving NEEDS with New Advances in Technology

The underlying technical framework of NEEDS is continuously being refined to take advantage of advances in technological innovation as they are appropriate.

Below we list one upcoming advance made possible through the work of Educom's Instructional Management System Project (www.imsproject.org).

Evolving NEEDS with New Advances in Technology

- Participate with Educom's Instructional Management System Project
  - NEEDS (through the University of California) is a development partner of IMS
  - Emerging Metadata standards
  - The IMS Metadata fields and NEEDS cataloging fields are nearly a 1-to-1 match

www.imsproject.org

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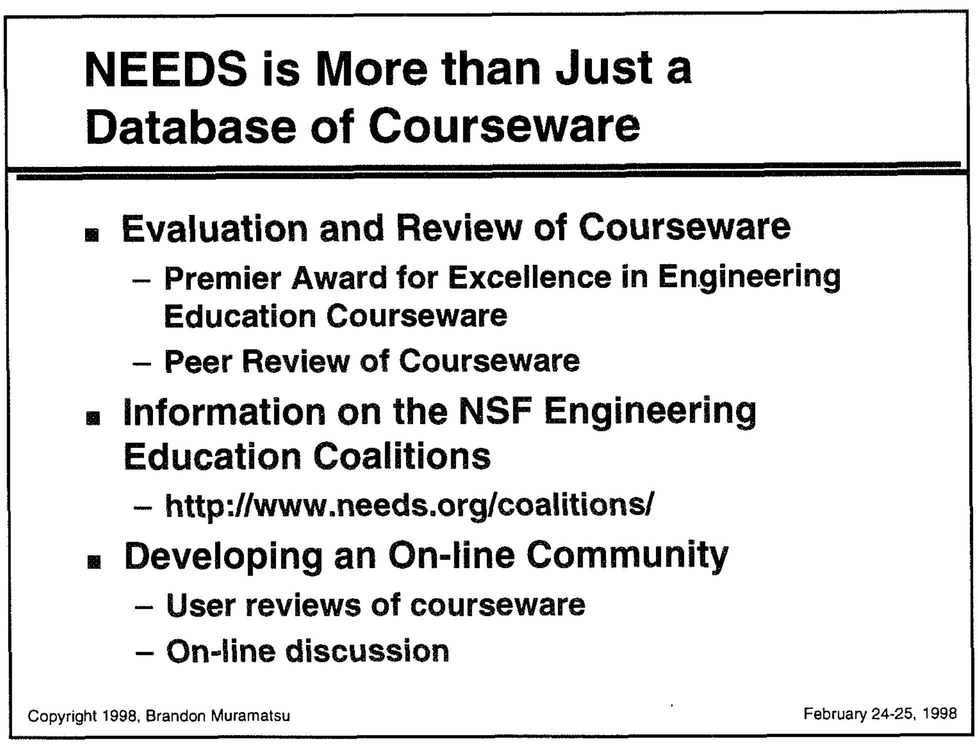
NEEDS is More Than Just a Database of Courseware

In addition to our efforts to expand NEEDS to support an on-line community of engineering educators, NEEDS supports a multi-tier courseware evaluation system including a national award competition, the Premier Award for Excellence in Engineering Education Courseware.



Quality Review of Courseware on the NEEDS Database

Courseware on NEEDS, as with any scholarly effort, requires review to assure quality and provide recognition. The Quality Review of Courseware effort was developed to advance the field of technology-enhanced learning review as well as continually raise-the-bar for excellent courseware. NEEDS has developed and is implementing a comprehensive, tiered peer review including non-reviewed, endorsed, and premier courseware.

In addition to the three areas already in operation, we are developing two new forms of review that go hand in hand with the development of our on-line engineering education community.

Quality Review of Courseware on the NEEDS Database

- **Establish Credibility of NEEDS as a Source of Quality Educational Material**
- **Enhance Recognition of Scholarly and Creative Effort of Courseware Developers**
- **Levels of Review**
  - **Non-reviewed**
  - **Gestalt Peer Review: Endorsed Courseware**
  - **National Competition: Premier Courseware**
  - **User Reviews: User experiences with courseware, contributed by community members**
  - **Feature Reviews: Extended reviews on NEEDS that highlight courseware**

New!

 February 24-25, 1998

Peer Review Criteria

The key ingredient to the peer review process was the development of evaluation criteria for engineering education courseware. These criteria are used to directly evaluate the premier courseware and form the basis for the gestalt, journal-type evaluations used to evaluate endorsed courseware.

Below are the criteria for the peer review of courseware and on the next three pages are the full criteria as applied to the Premier Award.

Peer Review Criteria

- Is content error-free?
- Are the target audience and educational goals consistent with courseware content?
- Can the courseware be used by an instructor other than the author?
- Should the courseware be endorsed?

 February 24-25, 1998

Premier Award Criteria

See the previous page for additional information.

Premier Award Criteria

See http://www.needs.org/premier/1998/criteria.html for more info

- Engineering Content
  - Is the content error free?
- Software Design
  - Is it well designed and usable?
- Instructional Design
  - Will students learn from the courseware?

We recognize that all the categories are interwoven.

 February 24-25, 1998

Premier Award Criteria (Cont'd.)

See the previous page for additional information.

Evaluation Criteria

- **Engineering Content:**
  - Accuracy of content
  - Organization of content
  - Consistency with learning objectives
- **Software Design:**
  - Engagement
  - User interface and navigation
  - Interactivity
  - Multimedia use
  - Technical reliability

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Premier Award Criteria (Cont'd.)

See the previous page for additional information.

Evaluation Criteria (Cont'd.)

- Instructional Design:
  - Interactivity
  - Cognition/conceptual change
  - Content
  - Multimedia use
  - Instructional use/adaptability

 February 24-25, 1998

Premier Courseware of 1997

Copies are available by emailing premier@needs.org or stop by the NEEDS Booth (#123) at ASEE 1998 in Seattle, WA.

- Virtual Disk Drive Design Studio - Prof. Alice M. Agogino, aagogino@me.berkeley.edu, University of California at Berkeley
- Drill Dissection and Bicycle Dissection - Prof. Sheri D. Sheppard, sheppard@cdr.stanford.edu, Stanford University
- Mars Navigator - Prof. Kurt Gramoll, gramoll@ou.edu, University of Oklahoma

Premier Courseware of 1997

- Virtual Disk Drive Design Studio
- Drill Dissection and Bicycle Dissection
- Mars Navigator

See http://www.needs.org/premier/1997/ for more info

Visit us in Booth 123 at ASEE 98

Distribution

1300 Copies to FIE '97 Participants
300 Copies to Engineering Deans
500 Copies available at ASEE '98

February 24-25, 1998

1998 Premier Award Competition

We are now accepting submissions for the 1998 Premier Award Competition. Full submission information can be found at http://www.needs.org/premier/1998/.

1998 Premier Award Competition

- Submit by July 10, 1998 to be eligible for the 1998 Premier Award Competition
- To be presented at FIE 1998, Tempe, AZ
- See http://www.needs.org/premier/1998/ for more info

Visit us in Booth 123 at ASEE 98

February 24-25, 1998

Continue NEEDS as a Service to the Engineering Education Community

Our long term goal is to continue NEEDS as a service to the engineering education community.

Goals:

- Continue NEEDS as a Service to the Engineering Education Community
  - Transition from a research to a service organization
  - Dissemination vehicle for courseware developers
  - Bridge the gap to an NSF-sponsored digital national library

The Coalitions are taking the lead to bridge this gap and we invite all interested parties to participate.

February 24-25, 1998

Digital National Library

One program currently under development at NSF is the development of a digital library to support Science, Mathematics, Engineering, and Technology Education.

A Digital National Library

Should NSF establish and fund a Digital National Library for Undergraduate Science, Mathematics, Engineering and Technology?

- **April 18, 1996 - NSF Committee Meeting (LIBUSE)**
  - "Towards a National Library for Undergraduate Science Education Resources in Science, Mathematics, Engineering and Technology"
- **August 7-8, 1997 National Research Council**
  - Digital National Library for SME&T Education Workshop
- **March 13, 1998 - NSF-DUE**
  - SMETE-Lib Steering Committee Meeting
- **Later 1998 - SMETE-Lib Workshop**

 February 24-25, 1998

Contact Information

See below.

References

- Agogino, A. M. and Wood, W. H., III, "The Synthesis Coalition: Information Technologies Enabling a Paradigm Shift in Engineering Education," keynote talk, in *Hyper-Media in Vaasa'94: Proc. of the Conference on Computers and Hypermedia in Engineering Education*, M. Linna and P.Ruotsala (eds.), Vaasa Institute of Technology, 1994, pp. 3-10.
- Agogino, A. M. and Muramatsu, B., *Expanding the National Engineering Education Delivery System as the Foundation for an On-line Engineering Education Community*, Proposal to the National Science Foundation, March 1998.
- Agogino, A. M. and Muramatsu, B., "The National Engineering Education Delivery System (NEEDS): A Multimedia Digital Library of Courseware, *Int Journal of Engineering Education*, Vol. 13, No. 5, 1998 (to appear).
- Eibeck, P., "Criteria for Peer-Review of Engineering Courseware on the NEEDS Database," *IEEE Transactions on Education*, Special Issue on the Application of Information Technologies to Engineering and Science Education, Vol. 39, No. 3, Aug. 1996, pp. 381-387. URL: http://www.needs.org/needsinfo/papers/IEEE96.eibeck/index.html.
- Synthesis Coalition and NEEDS, *Premier Courseware of 1997*, three CD-ROM set, Berkeley, CA: Synthesis Coalition and NEEDS, 1997.

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The Educational Object Economy

Martin J. Koning-Bastiaan
Apple Computer, Inc.
Cupertino, CA

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The Educational Object Economy

Martin J. Koning-Bastiaan
Research Scientist
Educational Object Economy
Apple Computer, Inc.
1 Infinite Loop Drive
Cupertino, CA 95014

Martin J. Koning-Bastiaan, Apple Computer, Inc., Cupertino, CA gives NASA and the University of Virginia permission to publish the conference paper entitled, *The Educational Object Economy*.

Educational Object Economy

The EOE (http://eoe.apple.com) is a community of educators, developers and businesses working together to use, create, and collaborate upon educational Java objects on the web. Currently, there are over 1750 educational Java objects in the library, covering virtually every subject area. These interactive simulations, illustrations, and exercises are available at no cost for anyone (with web access) to use.

In contrast to many efforts, the EOE is a member-generated community where members can build upon their strengths. Instead of requiring educators, for instance, to learn Java in order to affect which Java objects get created or modified, they can use their expertise (pedagogical and subject-related) to use the educational objects and give suggestions to (or even work with) Java developers to make better Java objects.

EOE: A global community for web based learning tools in Java
Join educators, researchers, software innovators, & businesses working together.

EOE Overview

The Educational Object Economy is an NSF funded research project at Apple Computer, Inc. The focus of the project is to prototype and explore web-based learning communities. The community that we have developed centers around educational Java applets. The EOE currently has the world's largest repository of educational Java objects.

EOE Overview

- NSF funded research project
- Java in education and distributed learning
- Over 1750 Java educational applets
- Community of educators, developers, and businesses
- http://eoe.apple.com/

EOE Philosophy

The foundation of the EOE is a commitment to a member-generated community. Members add content, use and share resources, and collaborate with each other to improve or create objects. The EOE is also free of charge. The community encourages open source objects so that they can be shared and improved upon freely in the community.

EOE Philosophy

- Member generated site: ownership and participation
- Open sources encouraged: sharing and reuse
- Java: beyond static text and pictures
- Cooperative style and free of charge

What's In It For You?

The EOE uses a Filemaker Pro database with a built-in web companion. In addition to developing the community website with this inexpensive solution, the EOE also has released the structure of the community website for anyone to download and set up, free of charge. The EOE also encourages others to use, share, and improve upon the website technology.

What's in it for you?

- Free virtual community kit: "Generic Object Economy"
- Easy to set up and maintain
- Empowers members to gather, share, and add value to each other's work
- Added bonus: lots of educational content

What's In It For Educators?

Traditionally, the avenues for educator input into educational software have been very limited. Educators could build it themselves, work with a group, or perhaps (if lucky) be able to give feedback when testing the product. Most of these avenues involve a significant amount of time, expertise and effort. The EOE's community-based philosophy encourages multiple levels of contribution. Those with little time can contribute reviews and use the objects, those with more time and interest may work with some technical members of the community to improve upon or create new objects. In this way a broad base of educators can be involved in the development of educational material.

What's in it for Educators?

- Community: build upon strengths
- Lots of input into what gets created or modified (and attribution)
- Anything you contribute is valuable - multiple levels of contribution encouraged
- Educate better with technology - not just a mantra or hype

Success to Date

The EOE community is growing quickly, with new applets, members, and resources being added daily. The EOE model for on-line communities is spreading daily through the GOE kit we have released, and the coordination of many previously disjunct educational efforts is proceeding rapidly.

Success to Date:

- Largest directory of educational Java applets
- Growing daily: members, applets, and other resources
- Spreading daily: others setting up their own Object Economies
- Helping to coordinate many educational efforts

A Tour of the EOE

The next few slides will be a virtual tour of the EOE, showing some of the (continually evolving) aspects of the EOE website.

A Tour of the EOE

- Front Page
- Library of Java Educational Objects
- Example Category: Engineering
- Example Object: Electromagnetic Spectrum Applet
- Example Member's Page

Front Page

Newly added Members, Java Objects, Resources, and Events are shown, in addition to a member- submitted “feature of the week” and an “applet of the week.”

The navigation area is on the left hand column.

EOE: A global community for web based learning tools in Java
Join educators, researchers, software innovators, & businesses working together.

3/19/98 — **Educational Object Economy**

Contents

What is the EOE?
A brief overview of the project, and ways that you can get involved.

People
This is our members page.

Library
Find Java Applets here.

Resources
Resource pages on subjects of interest to EOE members.

Business Models
An exploration of potential business models for the Internet.

Papers
Some papers written by members, including past features of the week.

Discussions
Many different topics of interest to the EOE community.

Newsletters
Our EOE newsletter archives--find out what's been happening!

Create your own Object Economy! Click here:
Download The GOE!

News & Events

Here's what's happening in the EOE. [Complete List]

3/21/98: TYC 21 Physics Conference
Jim Spohrer of the EOE will keynote at the TYC meeting.
3/19/98: The EOE in Cairo!
Byron Henderson of the EOE reports from Cainet '98
3/13/98: EOE in Higher Ed
"The Mac is Alive and Well In Engineering Higher Ed," By Craig Hunter

New Stuff!

Here are some of the new People, Applets, and Resources.

New Members:
3/18/98: Gunnar Brückner, United Nations Development Programme UNDP
3/18/98: Ann Marion, Houghton Mifflin Company
3/16/98: William Anger, Reference Librarian

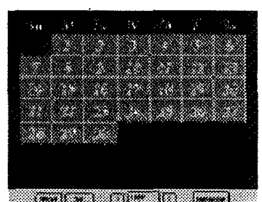
New Applets:
3/18/98 TeamStats
3/18/98 WebExamination
3/18/98 Music Lyrics Quiz

New Resources:
3/17/98: Debian Social contract
3/16/98: Database Publishing with FileMaker on the Web by Maria Langer
3/16/98: FileMaker Pro 4.0 Companion by Maria Langer

Feature of the Week

Steps to Using Java Applets in the Classroom. See how the EOE is finding use in classrooms in India, and what they have learned! By Anu Madra, Shefali Jain, & Steven Rudolph.

Applet of the Week



Calendar Magic, by Alexander Bogomolny. Also has an Educator Comment by Anu Madra!

Object Library

This is the main library page, with a breakdown of all the objects in the library by Dewey decimal classification.

Members can add objects from this page, in addition to browsing the recent reviews and educator comments.

· E/W · Educational Object Economy

Object Library

Welcome to the EOE community library! Click on the subject you wish to browse, or search for an applet using our handy form.

- 000 Generalities (79)
- 004 Computer Science (252)
- 100 Philosophy & Psychology (75)
- 200 Religion (5)
- 300 Social Sciences (22)
- 330 Economics & Business (116)
- 400 Language (71)
- 500 General Science (21)
- 510 General Mathematics (92)
- 512 Algebra (21)
- 513 Arithmetic (60)
- 515 Calculus & Analysis (75)
- 516 Geometry (129)
- 519 Probablility & Statistics (62)
- 520 Astronomy (32)
- 530 Physics (441)
- 540 Chemistry (92)
- 550 Earth Sciences (32)
- 570 Life Sciences (91)
- 600 Engineering (237)
- 610 Medicine & Health (48)
- 700 Arts & Music (81)
- 790 Sports & Games (165)
- 800 Literature (7)
- 900 History & Geography (52)

Other Options:

Add an Object
Make a contribution to the EOE community by adding an object URL to our library!

Advanced Search
If you know the name of the object you wish to find, you can use the box at the bottom of the page to find it. If you wish to have more advanced searching capabilities, click here.

View Submitter Name List
See graphical representations of applet contributions from the growing EOE community.

Recent Object Reviews
Check out the latest reviews of applets in our database.

Recent Educator Comments
Check out the latest Educator Comments on applets in our database.

Look For: Applets
[Search]

EOE Home | Info | Events | Library | People | Resources | Papers
Apple Computer, Inc. East/West Group

Engineering Hitlist Page

Thumbnail pictures of most of the applets are available, which allows for more effective searching and browsing.

· E/W · Educational Object Economy

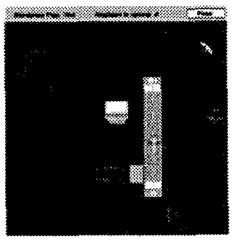
Objects Found

Image Key:

= Has been Reviewed, = Has Educator Comments, = Has IMS Metadata

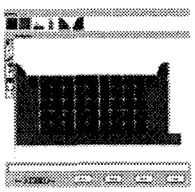
Displaying records **1** thru **10** of **237** records found
(**10** records displayed)

[Next]



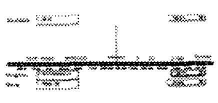
Airport Pattern Simulator

Category: 600 Engineering
Source Code Available: yes
Date Entered: 05/06/1997
Description: Simulation of planes landing at an airport
[More Info]



BridgeBuilder

Category: 600 Engineering
Source Code Available: yes
Date Entered: 06/26/1997
Description: Build your own bridge and experience forces. Your bridge will collapse under the load of cars driving over the bridge in the case of instability.
[More Info]



Electromagnetic Spectrum Applet

Category: 600 Engineering
Source Code Available: No
Date Entered: 10/7/97
Description: Click and drag on the electromagnetic spectrum to see the relationship between wavelength and frequency.
[More Info]

Click here for applet.

Stability Simulation

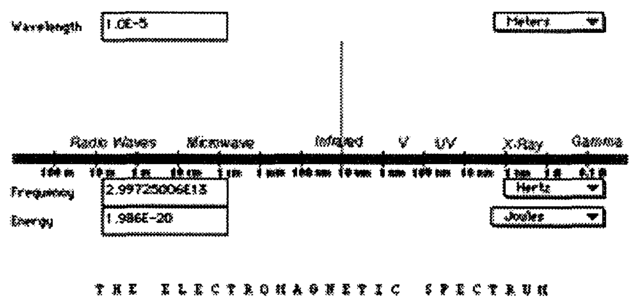
Category: 600 Engineering
Source Code Available: Yes
Date Entered: 12/3/97
Description: Simulation of aircraft stability-- Change the center of gravity and see how the stability for the aircraft changes.
[More Info]

Detailed Object Page

This page shows more detail than the hitlist page, as well as reviews, educator comments, and metadata members have contributed.

· E/W · Educational Object Economy

Electromagnetic Spectrum Applet



URL:	http://www.seds.org/~smiley/java/SpectrumTuner/
Name:	Electromagnetic Spectrum Applet
Description:	Click and drag on the electromagnetic spectrum to see the relationship between wavelength and frequency.
Subject:	600 Engineering
Author:	Guy McArthur
Author E-mail:	smiley@seds.org
Source Included:	No
Submitter:	Leslie Bondaryk
Submitter E-mail:	lbondaryk@pws.com

Have you checked out this applet? Write a review! Add an Educator Comment! Add some Metadata!

Review This Applet! | Add Educator Comment! | Add IMS Metadata!

John Cherniavsky, 10/21/97, rating=3 (Good)
Works
It works and gives the conversions and energy and frequency etc - could be a useful tool in a larger EE suite.

Look For: Applets

Search

Member's Pages

Members have their own pages with their information and perspectives on issues of interest to the EOE community.

• E/W • Educational Object Economy

Leslie Bondaryk
Founding Member

Name:	Leslie Bondaryk
Organization:	PWS Publishing Company
Address:	20 Park Plaza Boston, MA 02116
Phone #:	(617)368-3914
Fax #:	(617)338-6134
Email:	lbondaryk@pws.com
Home Page:	http://inbox.thomson.com:9966/~lbondaryk/
Member Since:	8/6/97
# of Applets Entered:	26
# of Resources Entered:	1

Personal Background:
Interest and work in Engineering Education dating back to 1986, Bachelor's in Electrical Engineering, MIT, 1988, Masters in Electrical Engineering, U.C. Santa Barbara, 1990. I'm currently the Manager for Technology Development at PWS Publishing Company, an Engineering and Computer Science Publisher. In this capacity, I help to engineer and produce educational software, sometimes as primary developer, sometimes as an editor, sometimes as an interface and usability designer, and sometimes as a producer.

How to Get Involved

There are many ways to get involved, from simply adding a review to an applet, collaborating with other members to create an educational object, to setting up your own on-line community with the GOE.

How to get Involved:

- Visit the site: http://eoe.apple.com
- Become a member
- Add your own value
- Download and set up your own GOE!

A Complex System Perspective to Computer-Assisted Learning

Alfred W. Hubler and Candace A. Martinez
University of Illinois at Urbana-Champaign
Urbana, IL

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A Complex System Perspective to Computer-Assisted Learning

Alfred W. Hubler and Candace A. Martinez
Center for Complex Systems Research, Beckman Institute, 405 North Mathews Avenue
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Web technology has made it possible for the Internet to penetrate a large proportion of American society. The educational sector has lagged behind the progress curve, however. This lag in the application of technology in education is due not only to financial reasons but also because education is more than information delivery and simulation. To teach a student via the web at least two components are required: a human computer interface that resonates with the student and artificial intelligence that understands specific areas of knowledge and applies appropriate responses. It is in this context that we study an asynchronous learning environment, CyberProf™, where we apply several fundamental complex system paradigms to human computer interaction: nonlinear resonances applied in a Digital Mirror, dynamical reconstruction applied in a Field-Specific Tutor, and control of chaos applied in a Five-Senses Human Computer Interface. To measure the effectiveness of the new learning environment we propose using Differential Concept Analysis (DCA). In DCA we monitor students' actions step by step, determine which concepts the students are using, in which sequence the concepts are used, and if the students are able to substitute and alter the sequence of the applied concepts.

A Complex System Perspective to Computer-Assisted Learning
Alfred W. Hubler and Candace A. Martinez

Teach a Student via the Web

- Human-computer interface that resonates with the student
- Artificial intelligence that understands specific areas of knowledge and applies appropriate responses

Asynchronous Learning Environment

- CyberProf™

Fundamental Complex System Paradigms Applied to Human Computer Interaction

- Nonlinear resonances
- Dynamical reconstruction
- Control of chaos

Measure Effectiveness of New Learning Environment

- Differential Concept Analysis

Introduction

Complex systems are systems with a large flow [1]. Large flow could refer to a fluid flow resulting in complicated dynamics and structures such as turbulence; or a large flow might refer to a system with a large current that results in complicated, ramified structures such as lightning. A large flow, however, can also refer to a large flow of knowledge, giving rise to complicated social behaviors in schools and universities. In complex systems research methodologies are being developed to model, predict, and control some of these complicated emerging structures and dynamics. Complex system paradigms provide intuition on handling complicated systems.

In 1967, Ilja Prigogine became famous for his finding that open chemical systems, systems with a moderately large throughput of chemicals, are attracted to the state of minimum entropy production, i.e., the state where the smallest amount of disorder is produced and the least amount of energy is wasted [2]. In 1977 he received the Nobel Prize for this finding. Later, other paradigms, including the principle of the dynamical key [3], were discovered. These paradigms have had important applications in engineering, such as transistors that are extremely energy efficient. Even stock market forecasting has become an important application of complex system methodologies. Yet, to date, very little has been done in applying complex system methodologies to problems in knowledge management and delivery despite the steady decline of American students' mathematics and science scores on international standardized tests.

Complex Systems (Systems with a Large Flow)

- Fluid flow resulting in complicated dynamics and structure (turbulence)
- Large current resulting in complicated ramified structures (lightning)
- Large flow of knowledge

Ilja Prigogine

- 1977 Nobel Prize winner

Three Fundamental Complex System Paradigms and the Digital Mirror

Specific applications of three fundamental complex system paradigms are studied to gain some insight and to model the tutoring process: Nonlinear Resonances [3] applied in a Digital Mirror, Dynamical Reconstruction [4] applied in a Field-Specific Tutor, and Controlling Chaos [5] applied in a Five-Senses Human Computer Interface.

The Digital Mirror applies our current understanding of resonances to human computer interfacing. The Digital Mirror will be a kind of on-line video telephone that "mirrors" or replicates the physical appearance and voice of the computer user. When the user logs onto a given mathematical or science program, the Digital Mirror will appear on the computer screen as a small icon or figure. The icon will look and talk like the computer user, but it will present and communicate the information and knowledge provided by the Field-Specific Tutor.

Three Fundamental Complex System Paradigms

- Nonlinear resonances applied to a Digital Mirror
- Dynamical reconstruction applied in a Field-Specific Tutor
- Controlling chaos applied in a Five-Senses Human Computer Interface

Digital Mirror

- On-line video telephone mirrors physical appearance and voice of user
- Will appear as small icon or figure

Field-Specific Tutor and Five-Senses Human Computer Interface

The Field-Specific Tutor is an interactive, educational software system based on the concept of dynamical reconstruction. It provides a mathematical/quantitative understanding of student/user input that not only analyses and parses the input but also gives appropriate feedback. The input can be manifested in different ways: typed natural language, voice, graphical or symbolic (such as algebraic equations or formulas for macromolecules). As students work through sets of problems, the Field-Specific Tutor, in the form of an on-screen, digital mirror "person," will analyze the conceptual understanding of the students with DCA, interactively guide them through their assignments, talk to them, answer their questions and provide helpful hints when necessary. By implementing the Digital Mirror with the Field-Specific Tutor, students will actually be tutored by an on-screen "person" resembling themselves as they attempt to solve mathematical and science problems on the computer.

The Five-Senses Human Computer Interface is based on the idea of controlling chaos. Research has demonstrated that the control of five-dimensional chaotic systems typically requires bi-directional interaction with all five degrees of freedom. We assume that it is necessary to communicate with all five senses in varying degrees in order to achieve effective communication with a human being. Computer technology currently provides only a good uni-directional visual and auditory communication channel schema. Therefore, we propose investigating the senses of smell, taste and touch, and attempt to ascertain how bi-directional sensory technology can be linked to the existing interactive computer methodology to more effectively reach learners of diverse abilities.

Field-Specific Tutor

- Interactive educational software system – provides mathematical/ quantitative understanding of user, analyzes the information and gives appropriate feedback

Five-Senses Human Computer Interface

- Bi-directional interaction with all five degrees of freedom

Nonlinear Resonances and the Digital Mirror:
Galileo Galilei was probably the first to discuss resonances in "Discorsi a Dimostrazioni Matemache" (1638) [6]. He used the term resonance (risonanza) to describe the response of music instruments to sound waves (Latin "resonare" = to echo). In the eighteenth century Huygens [7] discovered that two mechanical clocks with a slightly different speed tend to synchronize if they are mounted on the same wall. In the synchronized state the energy exchange is extremal [8] and the oscillators are said to be at resonance [9]. Later it was shown [10] that for a large class of weakly coupled self-sustained oscillators [11] the period of the coupled system closely matches the period of the fastest oscillator [12]. This phenomenon [13] seems to be the key paradigm for control in neural regulatory systems, such as the coupling of the sine mode and the atrio-ventricular node in the human heart [14].

Nonlinear Resonances and the Digital Mirror

Resonance Theories:
- GalilioGalilei
- Huygens

Resonance in Quantum Physics and Applications

Resonance is also a fundamental paradigm in physical sciences and engineering. In quantum physics, Bohr [15] introduced the term *resonance frequency* for the radiation frequency of a decaying energy state. Breit and Wigner [16] used the concept of resonance to describe a sharp peak in cross sections for certain scattering events of particles in nuclear physics. In engineering and applied physics, most textbooks and review papers [17] define resonance as the largest response of a driven damped linear oscillator [18]. At resonance, the driving frequency of an external sinusoidal force matches the natural frequency of the driven oscillator [19]. This causes a large energy transfer to the oscillator. Technical applications of this concept are mostly in the area of electrical engineering, e.g., RLC circuits in which the power consumption [20] of the circuit reaches its maximum at resonance. Spectroscopic instruments are based on resonant driving forces since this yields a large signal-to-noise ratio for harmonic and weakly nonlinear oscillators.

Resonance in Quantum Physics

- Bohr
- Breit and Wigner

Applications

- Efficient energy transfer
- System identification

Nonlinear Oscillators and Principle of Dynamical Key

For highly nonlinear oscillators, the response to sinusoidal driving forces is typically small and complicated [21]. It can be determined with the Lindstedt-Poincare method, Guckenheimer and Holmes' averaging methodologies, Lichtenberg and Lieberman's secular perturbation approach, or Nayfeh and Mook's multiple scale methodologies. The resulting signal-to-noise ratio for spectroscopic instruments is small for sinusoidal driving forces [22]. Recently, it has been conjectured that a large energy transfer to nonlinear oscillators can be achieved by a special class of a-periodic driving forces: The control is most efficient if it resembles the natural dynamics of the system. This yields a high signal-to-noise ratio, which can be used for system identification with general resonance spectroscopy [23]. Other numerical studies of optimal controls of nonlinear quantum systems confirm this observation [24].

In summary, we expect controls to be most efficient if they mirror natural dynamics or are composed of natural dynamics and a small modulation. This paradigm is called the principle of the dynamical key. In information science, an important discovery in our comprehension of applying resonance occurred almost thirty years ago and resulted in the interactive computer program called ELIZA, the "on-line psychologist". The program mirrors the input of the user with slight modifications and has attracted millions of patient users for decades. Despite its success, ELIZA has never been used to communicate knowledge or studied from a theoretical perspective. The proposed Digital Mirror goes beyond discovery to date about ELIZA and its successors. It is based on all previous research conducted in the fields of resonances and the dynamical key.

Nonlinear Oscillators

- Lindstedt-Poincare method
- Guckenheimer and Holmes (averaging methodologies)
- Lichtenberg and Lieberman (secular perturbation approach)
- Nayfeh and Mook (multiple scale methodologies)

Principle of Dynamical Key

- ELIZA – interactive computer program (on-line psychologist) – users learn in the most efficient time saving manner in controlled environment

Dynamical Key Paradigm

The dynamical key paradigm is the result of years of research with complex systems and has shown us that it is possible to achieve a large response by using the natural dynamics of a system as the control force. When applied to computer communication this means that users can learn in the most efficient, timesaving manner in a controlled environment that mirrors their everyday experiences (Fig. 1).

Figure 1 shows an example of another implementation of a digital mirror. In this case the content of home pages of one hundred university students was categorized and statistically analyzed to determine student preferences. Some of the top categories were travel (Alaska) and cartoons. This information was used to generate the context of physics homework problems.

Dynamical Key Paradigm

- Result of years of research with complex systems
- Users can learn in the most efficient, time saving manner in a controlled environment

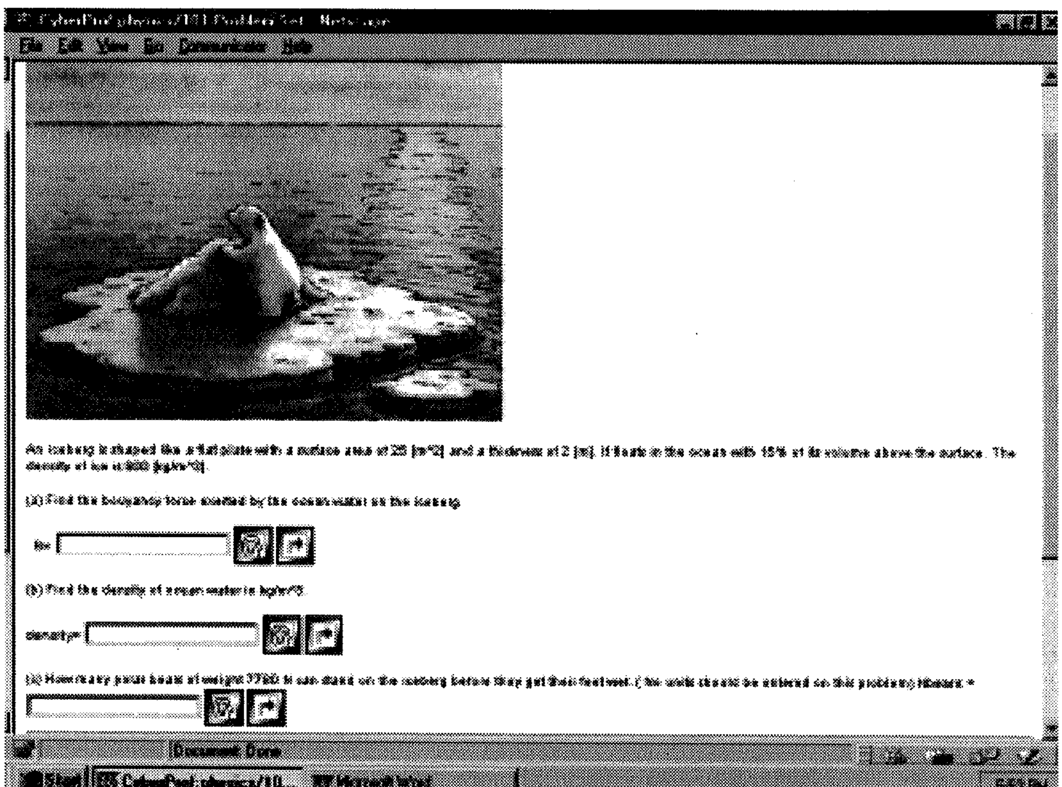

Figure 1

The Digital Mirror

The Digital Mirror could also be a mirror/resonance instrument that is installed on personal computers and recognizes and imitates (mirrors) the user's voice and image as it responds, gives advice and communicates with the user (Fig. 2). The educational ramifications of the Digital Mirror are staggering [35]. Preliminary studies have shown that students respond more readily to peer suggestions and advice as opposed to adult/teacher advice. If the computer "person" who interacts with the student during computer assisted math and science assignments is a peer who not only resembles the age and sex of the student but also the voice and physical appearance, the student's learning experience will be exponentially more beneficial. The Digital Mirror could be used for any situation in which the goal is to enhance interactive communication in other areas.

Figure 2 shows a simple implementation of an intelligent digital mirror. In the problem set several pre-algebra problems are presented with a picture of the student or a classmate.

The Digital Mirror

- Recognizes/imitates user's voice and image - gives advice and communicates with user
- Use in any situation where the goal is to enhance interactive communication

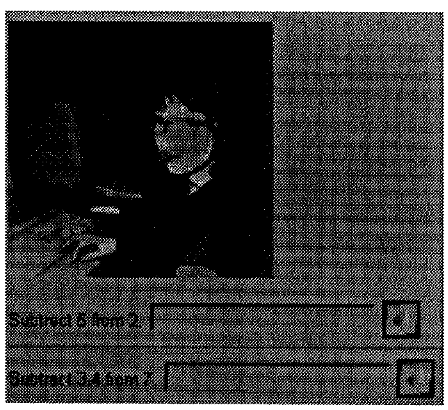

Figure 2

Dynamical Reconstruction: A Field-Specific Tutor and Differential Concept Analysis: Prior to the 1980s, researchers had always assumed that to study the dynamics of nonlinear systems with many degrees of freedom, time-series measurements of all the variables were necessary to generate state-space representations of the dynamics. In 1980 Packard et al. [25] and Ruelle noted that state-space representations of the dynamics could be reconstructed from a single time series through the use of delay coordinates. This delay-coordinate reconstruction would then be topologically equivalent to the dynamics of the true system. Whitney had shown much earlier [26] that any compact manifold with dimension m can be embedded in R $(2m+1)$. Takens [27] extended this in proving that an embedding can be obtained for any system from only a single time series by using $2m+1$ delay coordinates. While this combination of ideas thus far has been extremely useful in studying nonlinear systems, several difficulties arise in their application; for instance, in modeling how a student or a teacher parses and solves a given textbook word problem.

Study of Dynamics of Nonlinear Systems

- Packard and Ruelle: delay coordinates
- Whitney: embedding theorem
- Takens: embedding from a single time series

Flow Method

The most obvious difficulty in using delay coordinates is the issue of interpreting the results in the context of conventional models. If one is concerned only with forecasting, the method used for the modeling is irrelevant as long as it works. Successful modeling techniques based upon delay coordinates and/or partitioning the state space to generate local fits have been developed [28]. However, relating these models back to the conventional models or existing theories is often difficult if not impossible. Another important consideration is that Takens' theorem does not apply to systems with noise, i.e., experimental data. In the case of noisy experimental data, one must precisely define the meaning of embedding. We will call an embedding any representation for which any two observations X1(t) and X2 (t) within s, the noise amplitude, of each other are followed by X1($t+dt$) and X2($t+dt$) within the propagated error of each other. Another way of stating this could be that for any region of the state space, the variance of succeeding values is minimized.

In order to create a modeling technique in which existing information can be incorporated, the resulting model can be interpreted within the framework of conventional theories, with a reasonable signal-to-noise ratio; we base our technique upon the "flow method" [4]. The flow method is a procedure for reconstructing a set of coupled maps from the trajectories of the system in state space. This method works well even in the presence of hidden variables.

Flow Method

- Procedure for reconstructing a set of coupled maps from trajectories in state space
- Works well in the presence of hidden variables

The Field-Specific Tutor and Four Key Elements for Tutoring Process

The Field-Specific Tutor is a coupled map which imitates experimental observations of the tutoring process in a given field, i.e., first parses and solves a given word problem like a human tutor, then assists the student in solving the problem, based on the solution, and finally attempts to answer "what if" questions.

Preliminary studies suggest the following key elements for the tutoring process:

1. The tutor solves the word problem.
   - Parses the speech and labels the word types
   - Determines the objects, their properties, and relations (state space reconstruction) using a head centered speech analysis and the government and bonding approach
   - Determines the objectives, boundary, and initial conditions
   - Uses field-specific knowledge (equations, special vocabulary) and solves the problem.
2. The tutor checks the correctness of every statement in the work of the student and the reasoning of the student, based on the solution.
3. If the student does not know how to proceed (i) guides the student to the solution of the tutor if it is close or (ii) entrains the student to the tutor's solution from the beginning.
4. Accepts "what if" questions and repeats 1-3 for the modified question.

The dynamics of the tutoring process are not reproducible in contrast to the dynamics of an apple falling from a tree. However, the structure of the decision tree, which governs the tutoring process, may be highly reproducible, such as the equation of motion of a chaotic pendulum. The objective of dynamic reconstruction is to uncover the underlying structure of irreproducible processes. This approach could also be beneficial in the assessment of students.

Field-Specific Tutor

- Coupled map which imitates experimental observations of the tutoring process in a given field

Four Key Elements for Tutoring Process

- Tutor solves problem
- Tutor checks correctness of every statement in the work of the student and the reasoning of the student based on the solution
- Tutor guides the student to the solution or entrains the student to the tutor's solution from the beginning
- Accepts "what if" questions and repeats above steps

Assessment with Differential Concept Analysis:

When a student is asked to solve a math problem that requires several steps, he/she may choose a certain set of concepts and arrive at a correct answer (Fig. 3). If the same student is asked one week later to solve the same problem again he/she will almost certainly use a somewhat different approach. The number of different concepts which are used and the sequences in which they are used depend on how well the student understands the meaning and the usefulness of the different concepts. We propose monitoring the actions of the student step by step, represent them as trajectories in a space of concepts, and determine statistical properties of those trajectories. This methodology is called Differential Concept Analysis (DCA).

Students are asked to show the work and justify individual steps by a reference to the corresponding concept such as "additional property of an equation," or by a reference to the corresponding action, such as "add -2 to both members," or "subtract 2 from both members."

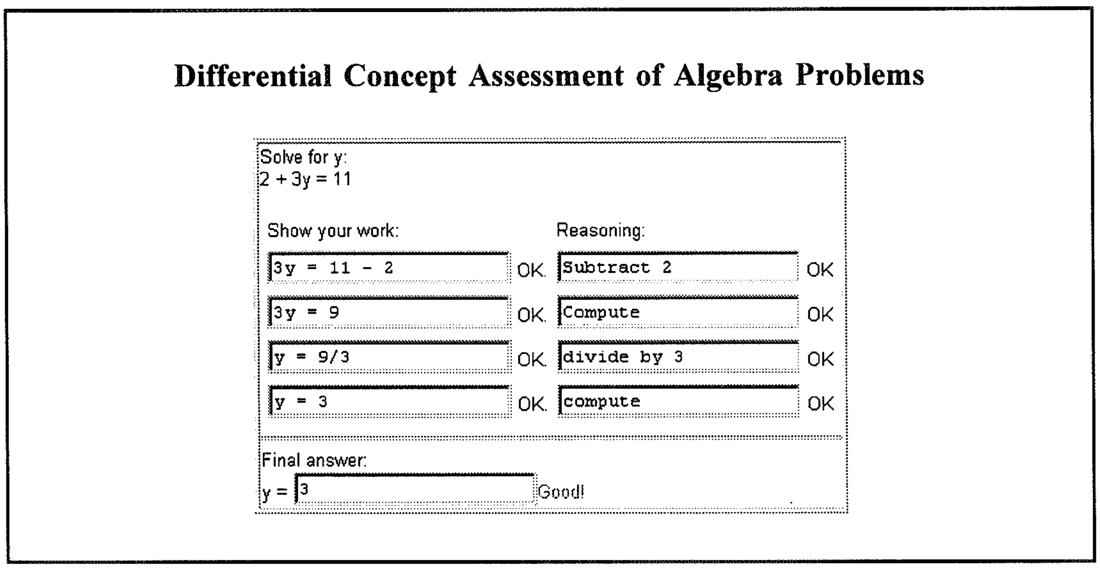

Figure 3

Evaluation of the Learning Environment

To evaluate the effectiveness of the learning environment and DCA as assessment tools, we propose additional examination of three functions of the student's performance: attention, persistence and learning.

Evaluation of the Learning Environment

- Student's attention
- Student's persistence
- Student's learning

Controlling Chaos and the Five-Senses Human Computer Interface:
To control a chaotic system, five ingredients are needed: a model of the experimental system, goal dynamics, a control requirement, the present state of all significant variables, and an actuator for every significant variable [1], [29]. The model is used to obtain a prediction of the state of the experimental system. The prediction is compared to the goal dynamics and with the imposed control requirement, the actual control force is calculated. A typical control requirement is to minimize the difference between the experimental dynamics and the goal dynamics.

The critical factor is the actuator for every significant variable (Fig. 4). If four perfect actuators or five noisy actuators control a system with five degrees of freedom, the control will almost certainly fail with the four actuators and be successful with a precision corresponding to the noise level of the actuators if the five actuators are being used [36].

Humans have five important senses. If we assume that tutoring requires the attention of the student and that getting the attention of the student can be considered as controlling the student, chaos control theory would suggest that the teacher has to control all inputs of the students, i.e. all five senses. In the commercial sector this concept is used in some areas. Books for small children deliver smell and sound, are printed on special paper which has a certain touch, and offer pretty images with candy and other food which children like. Students are diverse; some of them are visual learners while others have other preferences. If all senses can be stimulated through a Five-Senses Computer Interface the tutoring system can adapt to the preferences of the student.

Controlling a Chaotic System

- Model of the experimental system
- Goal dynamics
- Control environment
- Present state of all significant variables
- Actuator for every significant variable

Five Senses Computer Interface

We propose attaching to every computer a low-cost AD/DA converter to conduct commercial probes for certain gas molecules, commercial probes for liquid substances such as a PH-meter, possibly a microphone or a headphone if the built-in microphone and headphone adapters do not have the necessary specifications, a candy dispenser, and a specifically-designed touch actuator (Table 1). The touch actuator is attached to a force sensitive mouse and delivers both vibrations and heat. The olfactory response is provided through an ink jet printer, where substances with a strong smell are injected in the ink cartridges. The taste measurement is done with several probes for liquid substances in a test tube with water.

Figure 4. Mean square deviation between the target dynamics and the experimental dynamics versus the ratio of the noise level in the controls of a two-dimensional chaotic logistic map. The minimum mean square error occurs when the noise is proportioned among each control [36].

Five Senses Computer Interface

- AD/DA Converter
- Commercial probes
- Microphone/headphone
- Candy dispenser
- Touch actuator

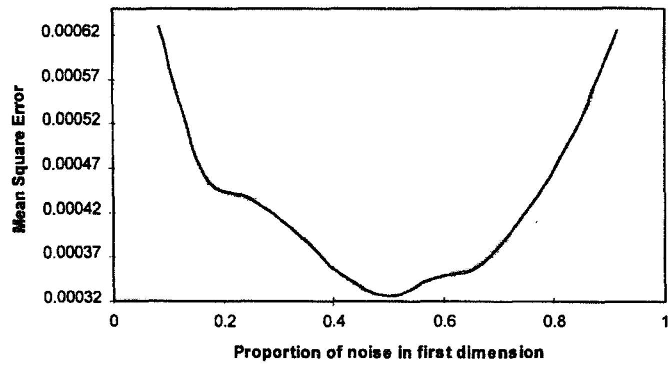

Figure 4

Table 1 - Experimental Realization of a Five-Senses Human Computer Interface

	Sound	Vision	Smell	Touch	Taste
Measurement	Microphone	Video Camera	Gas Probes	Force Mouse	Liquid Probe
Actuator	Headphone	Monitor	Ink Jet Printer	Heat, Vibrations	Candy Dispenser

Discussion

The efficient and rapid production of knowledge is one of the cornerstones of the U.S. economy, but the education system and the general public have difficulty adapting at the same pace. For example, a recent study of the U.S. Commerce Department shows that high-tech companies and universities have a hard time recruiting qualified domestic candidates in areas such as computer science and physics. There has also been a great deal of research on gender issues and standardization but only partial success has been achieved.

Specific Educational Challenges

- Poor performance of high school seniors in math and science [30], [31]
- Shortage of computer science graduates from U.S. universities [32]
- The store of human knowledge is doubling every five years [33]. How to retrain teachers and adapt curricula at that rate.
- The widening racial divisions in the U.S. [34]

CyberProf™ and CyberClub™

We believe that complex system paradigms will help design new technology-based teaching methodologies that will, in the long run, address these challenges. For the past three years, we have been developing an interactive, web-based educational software system called CyberProf™, which is currently being used in several undergraduate biology, chemistry, physics and economics classes at the University of Illinois at Urbana-Champaign. Implementing CyberProf™ and interactive technology, we have also developed and tested a web-authoring after-school program for at-risk middle school children called CyberClub™. CyberClub™ teaches mathematics and computer literacy to under-performing students at the Urbana Middle School by applying complex system paradigms to design new technology-based teaching methodologies. After nearly two years of operating CyberClub™, we have found that the participating students experience increased self confidence as they learn and progress, enjoy simple programming tasks, successfully learn to use the computer to solve simple math problems, and are willing to learn other academic courseware on the computer.

We propose applying a similar approach for tutoring math and science over the web at all levels to increase students' performance significantly in these areas.

CyberProf™

- Interactive web-based educational software
- Used in undergraduate biology, chemistry, physics and economics classes at UIUC

CyberClub™

- Web-authoring after school program for at-risk middle school children
- Teaches mathematics and computer literacy to under-performing students

Possible Concrete Achievements

The Digital Mirror will imitate the personal appearance and voice of computer users. It will level the playing field. The Digital Mirror will imitate the person who sits in front of the computer. Its voice and physical appearance will resemble the user's, irrespective of his/her ethnic background or quantitative skill set. Concurrently, the Field-Specific Tutor will interactively provide students with on-going comments and guidance in concrete subject matters as they carry out tasks and problems on the computer; again, regardless of whom they are or where they come from. It will provide comparable tutoring for all students, tailored to their specific level of conceptual understanding. The Five-Senses Human Computer Interface will allow students to use all five senses, including smell, to approach the learning process. In aiding skill mastery, the Human Computer Interface will holistically support and reinforce the teaching mission of the other two technological tools. With the rapid evolution of technology, many computation-intensive tasks like natural language processing [37] and educational software agents [38], have become feasible, even for personal computers. The complex system approach provides guidelines for applying these technologies in education.

Possible Concrete Achievements

1. Tutoring students in math and science on the computer and providing positive, constant feedback and encouragement using the Field-Specific Tutor (Dynamical Reconstruction). In the U.S. a typical high school teacher teaches five units per day with an average of 25 students per unit. Our studies suggest that it takes about ten minutes per student for a teacher to check and comment on his/her homework in a science or math course. This amounts to 1250 minutes per day for each teacher and, consequently, homework is typically not checked and commented on. On the other hand, such highly repetitive checking and tutoring tasks can be done by computers, thus releasing the teacher from the burden of grading the homework and giving the teacher an opportunity to spend his/her time on more creative subjects such as innovating the course curriculum.
2. Reaching out to, and providing academic knowledge to, a larger fraction of the U.S. population (including minorities, women and low-income individuals) by using the principle of the dynamical key, the leadership paradigm and the control of chaos.
3. Teaching the teachers and students simultaneously with courseware that includes recently tested scientific results through an algorithmic representation of scientific results (Dynamical Reconstruction).
4. Offering custom-designed, web-based training and tutoring on specific topics required by small groups of people around the country, which heretofore was too costly. Since authoring on the web can be easy and inexpensive, such training will become widely available.
5. Developing performance-based standardized computer assessment tools that test the conceptual understanding of the students.

Three Complex System Paradigms in Education, Other Key Paradigms and Concepts

Applications of three complex system paradigms in education (nonlinear resonances, dynamical reconstruction, and controlling chaos) have been discussed. There are several other key paradigms in complex systems which may provide useful applications: the leadership paradigm, the principle of minimum resistance, the simplification paradigm, the principle of marginal stability, and concepts such as singular motion, and "social systems are boundary-driven."

Three Complex System Paradigms in Education

- Nonlinear resonances
- Dynamical reconstruction
- Controlling chaos

Other Key Paradigms

- Leadership paradigms
- Principle of minimum resistance
- Simplification paradigm
- Principle of marginal stability

Concepts

- Singular motion
- Social systems are boundary-driven

Acknowledgment

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Internet-Based Teaching/Learning Tools In Structural Engineering Education

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Internet-Based Teaching/Learning Tools in Structural Engineering Education

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Internet-Based Teaching/ Learning Tools in Structural Engineering Education

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Outline

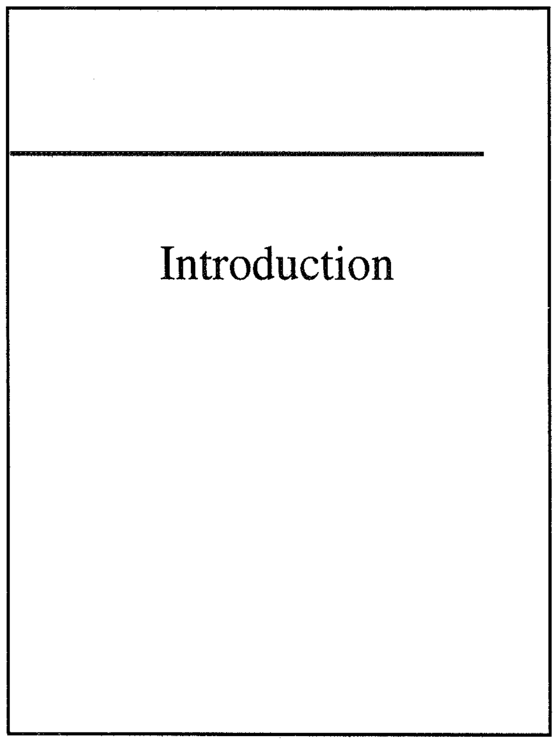
The presentation is divided into five parts. The first one provides a general background of the project in the context of engineering evolution. The second one introduces the concept of Engineering Forum. Next, Dr. Structure, the system developed at George Mason University, is described. Initial conclusions are also presented. The last part of the talk is the demonstration of Dr. Structure, which is available on a server at George Mason University.

Outline

- Introduction
- Engineering Forum
- Dr. Structure
- Conclusions
- Demonstration

Introduction

The Introduction provides the context of the presentation and explains, at least partially, why Dr. Structure, a new multimedia system for teaching steel structural design, was developed by the speaker.



Background

The background of Tomasz Arciszewski is briefly discussed, including his formal education in structural mechanics and in structural engineering, his design experience from several countries, his teaching in three educational systems (Poland, Nigeria, USA), and his work in the areas of inventive engineering and information technology.

Background

- Structural mechanics and engineering education
- Hands-on design experience from Poland and Switzerland
- Inventor with three patents in structures (Canada, Poland, USA)
- Research on inventive problem solving and information technology (machine learning, network computing)

History of Engineering

The entire history of engineering is briefly discussed, including its individual stages and the underlying engineering paradigms. Changes in engineering are driven by progress in science and in technology, and at present, the information technology revolution is having a significant impact on engineering, including engineering education. The author claims that we are now in the CyberSpace Age, when the dominant engineering paradigm is based on the extensive use of computer networks. In this context, engineering education will also soon become network computer driven.

History of Engineering

- Up to the end of 17th century, ***Age of Experience***, empirical experience
- 18th-19th century, ***Age of Reason***, conceptual understanding
- 19th century-1950, ***Age of Mathematics***, mathematical modeling
- 1950-1980, ***Computer Age***, computer modeling
- 1980-1995, ***Knowledge Age***, acquisition and utilization of knowledge
- 1995-today, ***CyberSpace Age***, use of computer networks

History of Engineering Education

When the history of engineering is considered, three main periods can be distinguished from the point of view of technology used. In the ***Chalk Era,*** a blackboard and a piece of chalk were education media. In the ***PC Era,*** a personal computer was widely used. Finally, in the emerging ***Network Era,*** computer networks and various related technologies of multimedia, virtual reality, etc., are becoming the media of engineering education.

History of Engineering Education

- 1874 B.C.-1970's, blackboard and chalk

  Chalk Era
- 1970's-1995, distributed and independent computer teaching/learning tools

  PC Era
- 1995-today, integrated and network-based computer teaching/learning tools,

  Network Era

Trends

At present, in civil engineering education four major trends can be observed. The reduction in the number of credit hours required to graduate is driven by both political and economic factors. The introduction of new IT-related courses simply reflects progress in science and technology. The fundamental change in terms of focus from structures to other areas reflects the growing demand for civil engineers in various non-structural civil engineering areas. Finally, universities are becoming more service oriented and many administrators want to consider students as customers who should be immediately happy after they receive their educational services. That leads to expectations of entertaining students and making them happy at any cost, including reduced requirements and amount of work required. All of these trends have a significant impact on structural engineering education.

Trends

- Reduction of the number of required credit hours to graduate
- Introduction of new IT-related courses
- Changed focus in civil engineering education from structures to USE, IT, etc.
- Need to entertain students

Actual Situation

At present, the situation in the area of structural engineering education is quite difficult. We have to deal with the reduced number of courses in structures. At the same time, students are much less motivated to study structures than before and expect nice and easy courses with a minimum amount of work.

Actual Situation

- ◆ Reduced number of courses in structures
- ◆ Student motivation level to learn structures is lower than before
- ◆ Strong pressure to make students happy and satisfied customers

Solutions

The present situation requires drastic solutions. The easiest one, but unacceptable from the ethical point of view, is to drastically reduce requirements making both students and administration happy. Another solution, chosen by the speaker, is to change the teaching/learning paradigm using information technology. This new paradigm should also allow students to learn how to acquire engineering knowledge later, when they realize the need to learn more.

Solutions

- Drastically reduce requirements
- ***Change teaching/ learning paradigm***
- Teach students how to learn later in the information technology era

New Paradigm

A new paradigm is proposed which will be based on the utilization of information technology, including network computing and multimedia systems. However, this paradigm will never be successful without human involvement in the learning/teaching process. Information technology in engineering is also a driving force behind the integration of various domains, which up to very recently were considered quite independent; for example, structural analysis and design, structural and mechanical engineering, etc.

> ### New Paradigm
>
> ... of teaching structural engineering will be based on:
>
> - Using network computing
> - Using multimedia presentations
> - Integrated human-virtual learning environment approach
> - Combining knowledge from various structural engineering domains, i.e., analysis and design

Engineering Forum

The new structural engineering learning/teaching paradigm is proposed in the context of Engineering Forum. The speaker believes that Engineering Forum will become a new engineering paradigm and its introduction will have tremendous impact on engineering.

Engineering Forum

Context

The concept of Engineering Forum has been proposed by the speaker in the context of "Information Market." Many futurists, including information technology experts, believe that Information Market is gradually emerging, and that during the next several years it will become the dominant paradigm of our civilization, as in the past, agriculture, manufacturing, or computing paradigms were.

Context

- Inspired by the concept of "Information Market"
- New engineering paradigm
- Engineering bridge to the 21st century
- Result of information technology revolution in engineering
- Driven by competition in manufacturing arena

Information Market Place

The concept of Information Market Place has been proposed by Professor Dertouzos of MIT. He claims that Information Market Place will become the central area of all human activities, as a traditional real market was in the past. In the future, we will be using a virtual world to work, shop, interact with other people, etc.

Information Market Place

- Proposed by Dertouzos
- Central area of human activities, as "market" was in the past
- Virtual world of the future
- An environment (social, political, technological, etc.) in which information is exchanged

Engineering Forum

Engineering Forum can be considered as an engineering component of the Information Market Place where all engineering activities will take place (or be supported) including professional practice and education. The speaker hopes, however, that the Engineering Forum will be better structured and managed than the Information Market Place.

Engineering Forum

- An engineering component of the Information Market Place
- Intended to support engineering in the 21st century, including teaching and training, also innovation
- Better organized and controlled than the remaining components of the Information Market Place
- To be considered in the context of virtual enterprise

Five Pillars

Five major components of Engineering Forum are identified and discussed. These components are necessary for Engineering Forum to exist and be useful for practicing engineers and educators.

Five Pillars

- ◆Engineering Process
- ◆Product Space
- ◆Cyber Tools
- ◆Product Knowledge
- ◆Computer Network

Engineering Process

Engineering Process is a new concept which covers all kinds of engineering processes, including those occurring in the educational arena. Understanding engineering in the context of a decision making process is important to be able to integrate engineering and to utilize information technology.

Engineering Process

- Starts when the need for a new engineering product is identified, and ends when the life cycle of this product is completed.
- A structured sequence of decisions called "Engineering Decisions," are made regarding the allocation of resources.

Engineering Forum Triangle

A formal process of decision making in engineering, including education, can be conducted only when ***Product Space*** and ***Product Knowledge*** are prepared for a given product, which can be in various forms, including structural design knowledge learned by students.

Engineering Forum Triangle

Engineering decisions are based on:

- Product Space
- Product Knowledge

Product Space

This general definition with roots in computer science can be used for the numerical, or nominal attributes, or for the combination of both.

Product Space

...is a representation space being used by a team of engineers, including engineering educators, during the life cycle of a given engineering product. It may also be a system of integrated representation spaces covering various aspects of a given product.

Product Knowledge

In the case of engineering education, product knowledge should be understood as engineering knowledge related to a given domain and which is supposed to be learned by students. Also, students should be able to learn more later, when their needs change, or simply when the state of the art changes.

Product Knowledge

...is engineering knowledge related to a given product which satisfies two conditions:

- is available in electronic form
- can be used in ***Engineering Process.***

Product Knowledge

Product knowledge has three major components as listed below. Formal knowledge is understood here as a combination of three components. First, concept library, which is an organized and hierarchical system of concepts. Feasible values of attributes simply determine the extend of the Product Space and decision rules provide qualitative knowledge unique for a given domain. Databases contain all relevant engineering data related to a given domain. Product models are of several kinds and are supposed to support all sorts of engineering activities.

Product Knowledge

- Formal knowledge: concept library, feasible values of attributes, and decision rules
- Databases
- Product models: concepts, graphical models, analytical models, etc.

Architecture

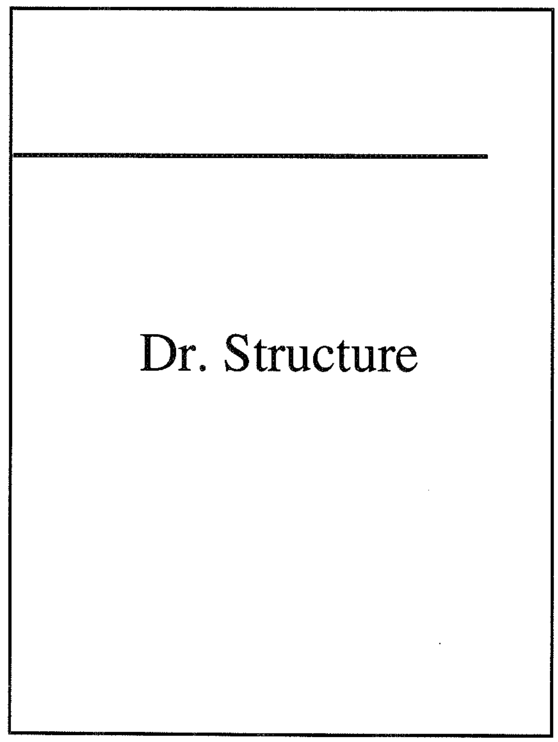
Transaction manager controls "traffic" and insures that no data is lost in the communication, including collaborative learning effort. Project server is a dedicated server which stores data, models, etc., related to a given project; in our case, to an educational project. Application server stores all application programs which are used for a given project. Vendor servers provide all project-specific data, i.e., data about their products through the Internet.

Architecture

- Transaction manager
- Users
- Project server
- Application server
- Vendor servers

Dr. Structure

Dr. Structure is a multimedia system for teaching/learning steel structural design. It has been developed by the speaker (general design, knowledge acquisition), his wife (HTML programming) and a friend (Java programming) working for Novel CyberSpace Tools. It is ultimately intended for commercial purposes. However, the access to Dr. Structure has been provided free of charge to students at George Mason University.



Motivation

The development of Dr. Structure has been motivated by several factors listed below. The speaker believes that multimedia systems could revolutionize teaching/learning of structural design and could lead to improved understanding of structures by students.

Motivation

- Unique design of the USE Program at GMU
- Limited interest in structures
- Low motivation level to learn structures
- Poor background in statics and physics
- My frustration with results
- NASA-supported research on inventive problem solving and NC

Objectives

Dr. Structure has been developed to meet several objectives provided below. Mostly, it is the result of the speaker's frustration with the progress of the learning of structures in the case of non-traditional civil engineering students.

Objectives

- Help students build a mental picture of structural knowledge
- Improve their progress in learning and their scores
- Interest them in the most interesting engineering domain: structural engineering
- Make students more comfortable with learning structures

Basic Assumptions

Dr. Structure is flexible in terms of ease of its expansion and modification. It is Internet-based and has been developed using HTML and Java programming languages. The speaker believes that the future of engineering education is in the integration of traditional instruction with the innovative use of various computer-based tools in the classroom and after classes.

Basic Assumptions

Dr. Structure is a learning and teaching tool which is:

- Flexible (easy to expand and modify)
- Internet-based
- Developed using HTML and Java programming languages
- Intended for use in the class by the instructor and by the individual students working separately

Knowledge

Structural design knowledge is in the form of a complex system of several interrelated components, as listed below. Therefore, all these components must be reflected in a useful multimedia system for teaching/learning structural design, as they are in Dr. Structure.

Knowledge

A complex system containing several interrelated components:

- Concepts
- Pictures
- Descriptions
- Procedures
- "Active Procedures" - applets

Steel Column Concept

As an example of how a design concept is presented, the concept of a steel column is provided below. Its definition, a general description, and the basic structural mechanics and engineering design assumptions present together this concept to the students.

Steel Column Concept

Steel Column is defined as a long structural member, usually vertically positioned, whose main function is to carry axial or eccentric longitudinal loading.

Basic Assumptions:

- a straight slender member
- supported at one or two ends
- under compression
- compressive forces applied along the longitudinal centroidal axis or parallel to it (eccentric loading)
- elastic behavior
- small elastic deformations
- stress and deformation analysis based on the Euler's model

Design Procedure

An example of a procedure, as it is presented to students, is shown below. This procedure is for the design of steel columns under axial loading and is closely reflected in the applet developed for designing steel columns. In this way, the student can learn the procedure in the general descriptive terms and then see it in action.

Design Procedure

1. ***Prepare Design Specification***

User determines axial loading, actual column length, support conditions, and steel yield strength.

2. ***Calculate K-Factor***

K-factor is computed based on the support conditions.

3. ***Determine the Adjusted Column Length***

Adjusted column length is computed based on the support conditions and the column length.

4. ***Estimate Section Area***

User estimates the cross section areas (allowable compressive stress = 14 ksi).

5. ***Calculate Slenderness Ratio***

The program computes slenderness ratio based on the smaller radius of gyration of the selected column and the previously computed adjusted column length.

6. ***Determine Allowable Stress***

This can be found in the Allowable Compressive Stress Table. The program does this for a user.

7. ***Prepare Stress Summary***

The allowable compressible stresses for the given column are compared to the actual compressible stresses. If the actual stress is greater than the allowable compressive stress, go to step 4 and select a larger section. If the actual stress is less than 95% of the allowable compressive stress, go to step 4 and select a smaller section. If the actual stress is less than the allowable compressive stress and more than 95% of the allowable compressive stress, congratulations. You have correctly designed the cross section of your column.

Applet

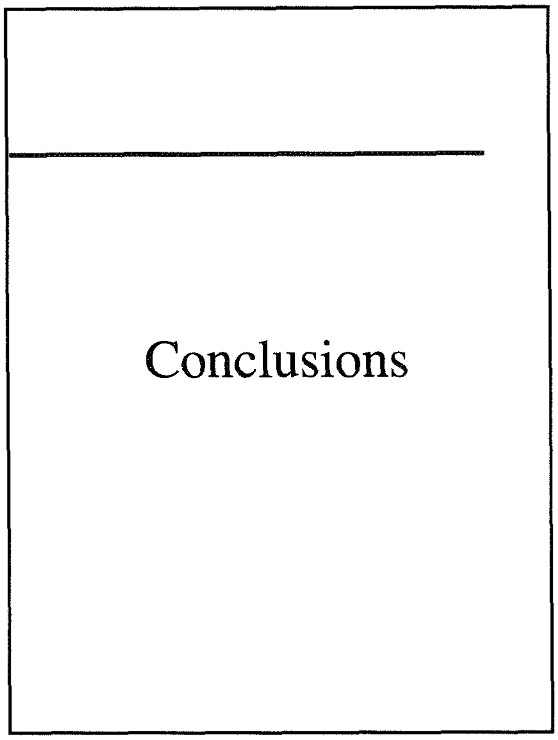
The applet for the stuctural design of steel columns under axial loading has been developed in Java by Witold Szczepanik of Novel CyberSpace Tools. It forces the user to conduct all steps of the design procedure, as presented in the previous transparency.

Applet

To be seen in demo

Conclusions

Several conclusions of the conducted Dr. Structure development are provided in the next transparency.



Initial Development Experience

The speaker was surprised by the amount of work necessary to develop Dr. Structure. The major problem was inconsistency of structural design and structural analysis knowledge which required writing all definitions, and that was comparable to the effort of writing a textbook.

Initial Development Experience

- Much more work than expected
- Structural engineering knowledge is inconsistent, particularly when analysis and design are considered jointly
- Available development tools are still relatively inflexible

Initial Teaching Experience

Dr. Structure was well received by students who easily accepted and used it in a natural way, as their predecessors used slide rules and electric calculators. However, among students no major attitude changes to structures were observed, to the speaker's great disappointment. This can be partially explained by the limited extend of Dr. Structure, which covers only the structural steel design of columns and beams.

Initial Teaching Experience

- New tool easily accepted by students and used without any complaints
- Still no outbursts of enthusiasm for structural engineering
- More knowledge is to be added to create a self-contained learning/teaching environment

Future Developments

In its present form, Dr. Structure covers only the quantitative aspects of structural design. However, its planned expansion will include teaching conceptual design, including inventive problem solving (speaker's area of interest). Also, more extensive structural design knowledge will be included; for example, knowledge related to the design of trusses, welded beams, etc. The addition of a machine learning component is being considered which could be based on inductive learning. Student performance evaluations should also be included, and that, probably, will be accomplished using the performance evaluation component of HyperLearning Meter developed at George Mason University in the Center for New Engineer.

Future Developments

- Conceptual design to be covered, including inventive problem solving
- More domain knowledge
- Additional applets for beam design, truss design, etc.
- Learning component based on machine inductive learning
- Performance evaluation component (HyperLearning Meter)

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Integration of CD-ROM Based Multimedia with the OU Intranet for an Asynchronous Environment to Teach Statics

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University of Oklahoma
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Integration of CD-ROM Based Multimedia with the OU Intranet for an Asynchronous Environment to Teach Statics

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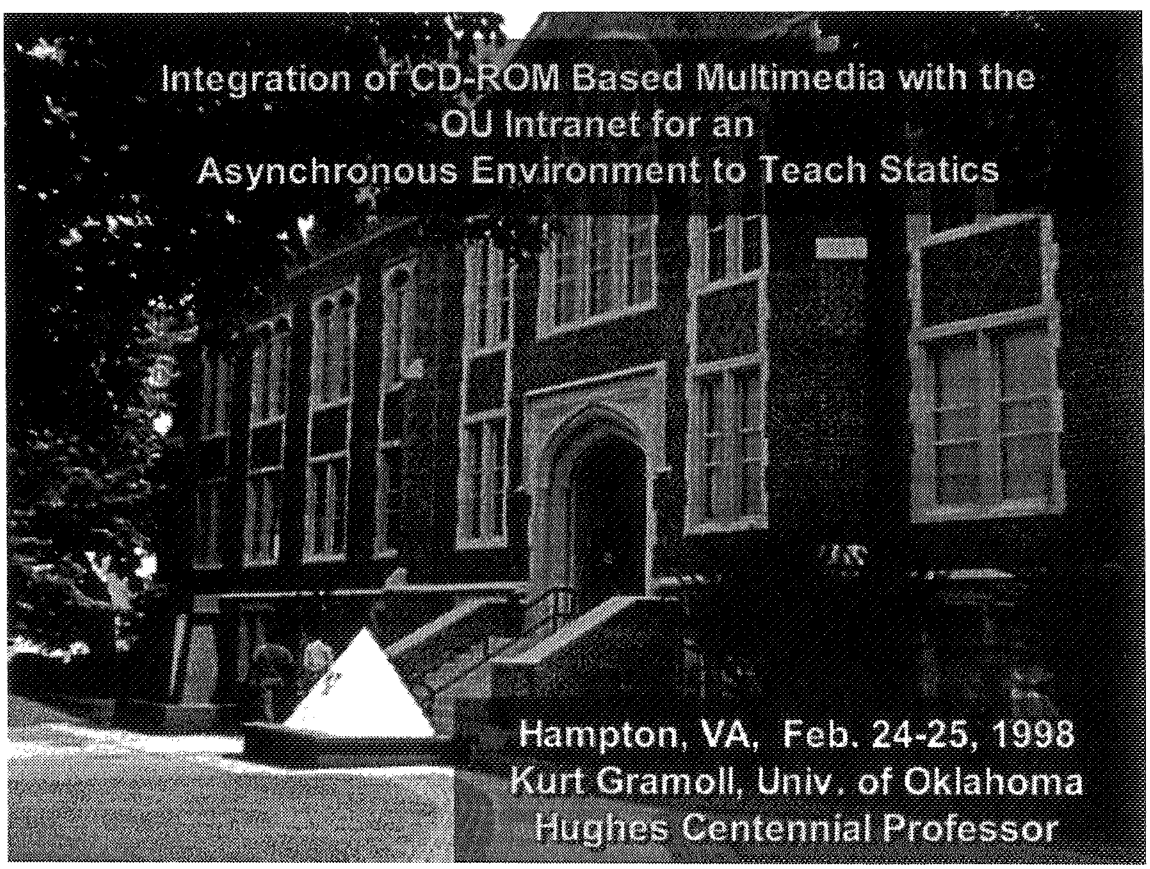
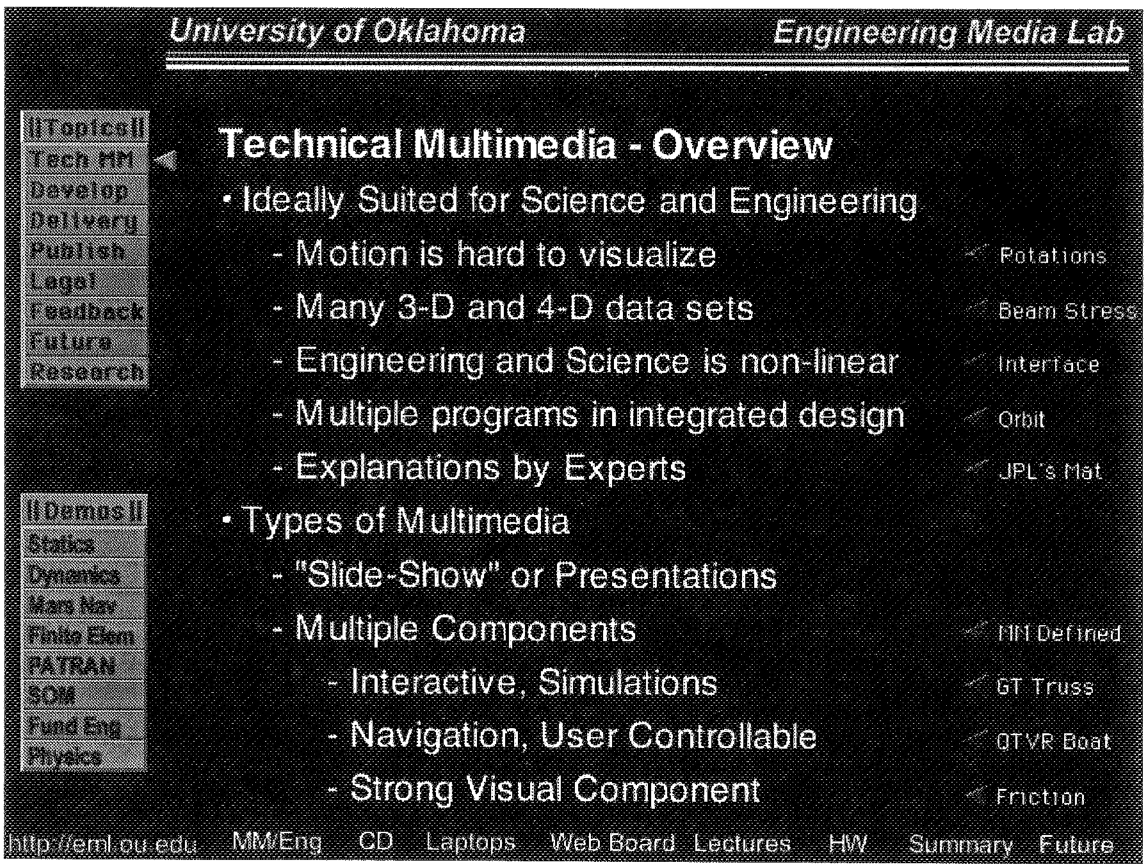
This presentation presents the current work being done at the University of Oklahoma in the School of Aerospace and Mechanical Engineering to teach Statics using laptop computers, CD-ROMs and the OU Intranet. Each of these components is playing a vital role in using technology to learn basic engineering. This presentation has two parts, first, a general discussion and demonstration of interactive media including work done by the author, and second, a detailed examination of the implementation of technology in the Statics class.



Technical Multimedia Overview

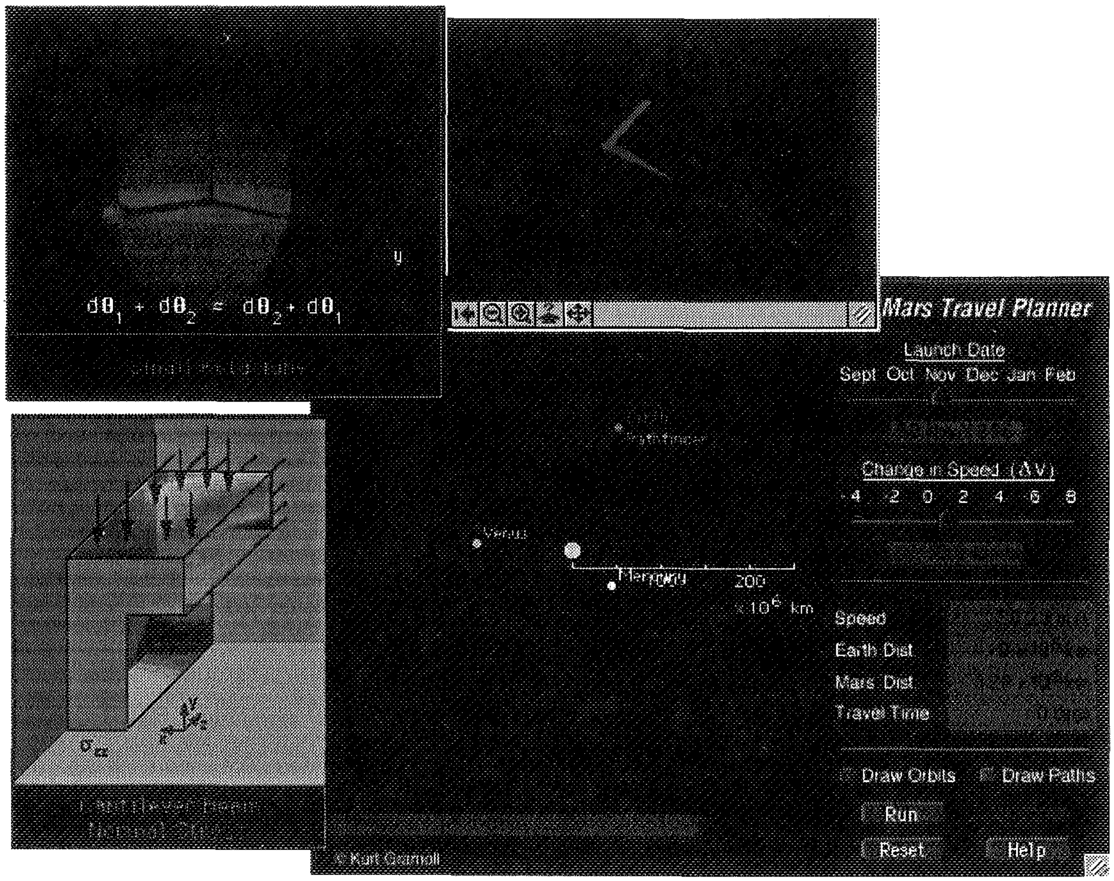
Multimedia is well suited for technical training and education due to its varied media possibilities. For example, time-based motion can be easily shown with computer animation. Data visualization is also important with science and engineering where values, such as temperature, vary in three dimensions. One of the more useful aspects is the ability to navigate information in a non-linear mode.

Not all multimedia needs to involve all media types. Each application of multimedia will dictate which combination of animation, sound, graphics, simulations, or video should be used. Since engineering has a strong visual aspect, technical multimedia should use three-dimensional animation. Simulations are also important so that students can learn from experimenting with various design ideas.



Examples of Technical Multimedia

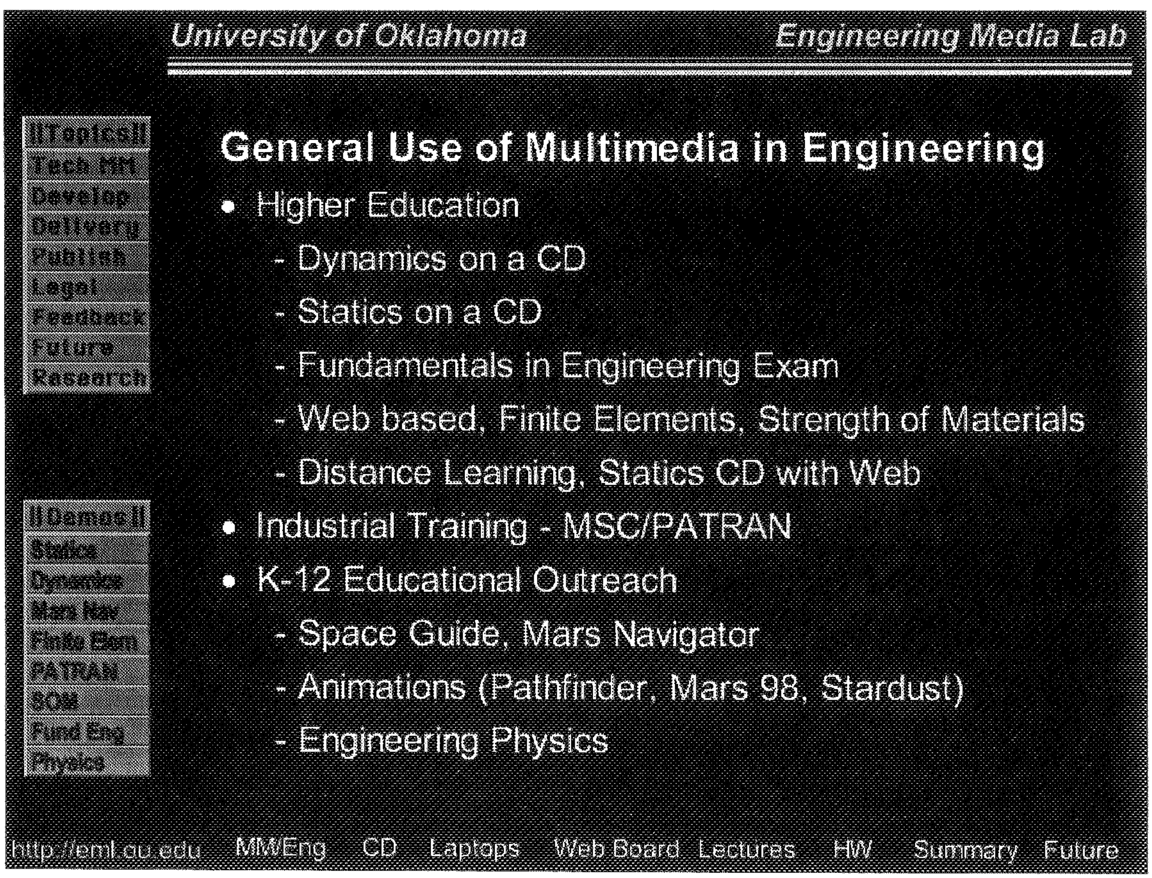
Shown below are various actual applications of animations and simulations. The small rotation animations help students learn how to add multiple rotation angles. The boat is a virtual reality object that can be manipulated by grabbing it with the computer cursor and rotating in any direction. This type of activity greatly assistants the user in visualizing three-dimensional vectors. The cantilevered beam is used in basic solid mechanics courses to help students visualize stress inside the beam. Students need to learn that stresses are three-dimensional and not two-dimensional. The last figure is from the Mars Navigator CD for high school students. This simulation is also used by CNN in their educational web site for space exploration. The students can learn how orbital mechanics work by experimenting with different launch dates and velocity changes.



General Use of Technical Multimedia in Engineering

In addition to the many possible components of multimedia, there are numerous applications. In higher education, the author has been involved with projects that include Dynamics, Statics, Review for the EIT, Finite Elements, and web-based delivery of courses. Higher education has been slow to use multimedia due in part to its traditional resistance to change and the high initial investment of time to develop quality courseware. The reward structure in higher education also inhibits professors from spending time in non-technical research.

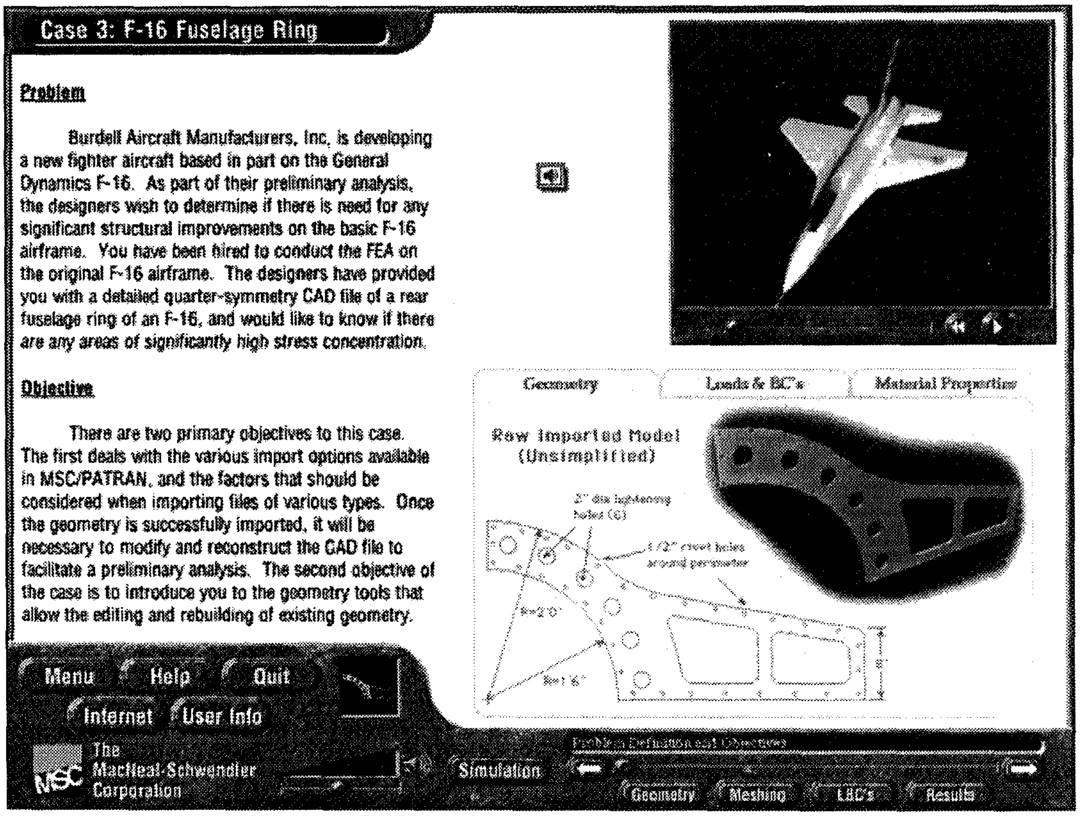
The other two main areas for technical multimedia, industry training and pre-college, have moved faster in implementing multimedia. The author recently completed a full CD-based training program for learning MSC/PATRAN. The program has been well received in industry. Not only does it provide an excellent learning environment, but also cuts costs by not requiring employees to travel to another location to take the company's sponsored course. In the K-12 area, the vast number of students makes a ready market for developing multimedia material. The author's experience in this area involves the Mars Navigator CD, Engineering Physics, and various animations for NASA's and JPL's outreach programs.



MSC/PATRAN Example and Demonstration

The MacNeal-Schwendler Corp. recently introduced the "Exploring MSC/PATRAN" CD to help industry learn its software program MSC/PATRAN. In addition to containing all the course notes that students would be exposed to in the normal weeklong course at MSC, the CD also has thirteen detailed case studies that explain all the major features of the program. Through the case studies, the students learn while completing structural analysis on typical engineering problems. Animations, simulations, sounds and graphics are all used together to help explain how to get the most out of the program.

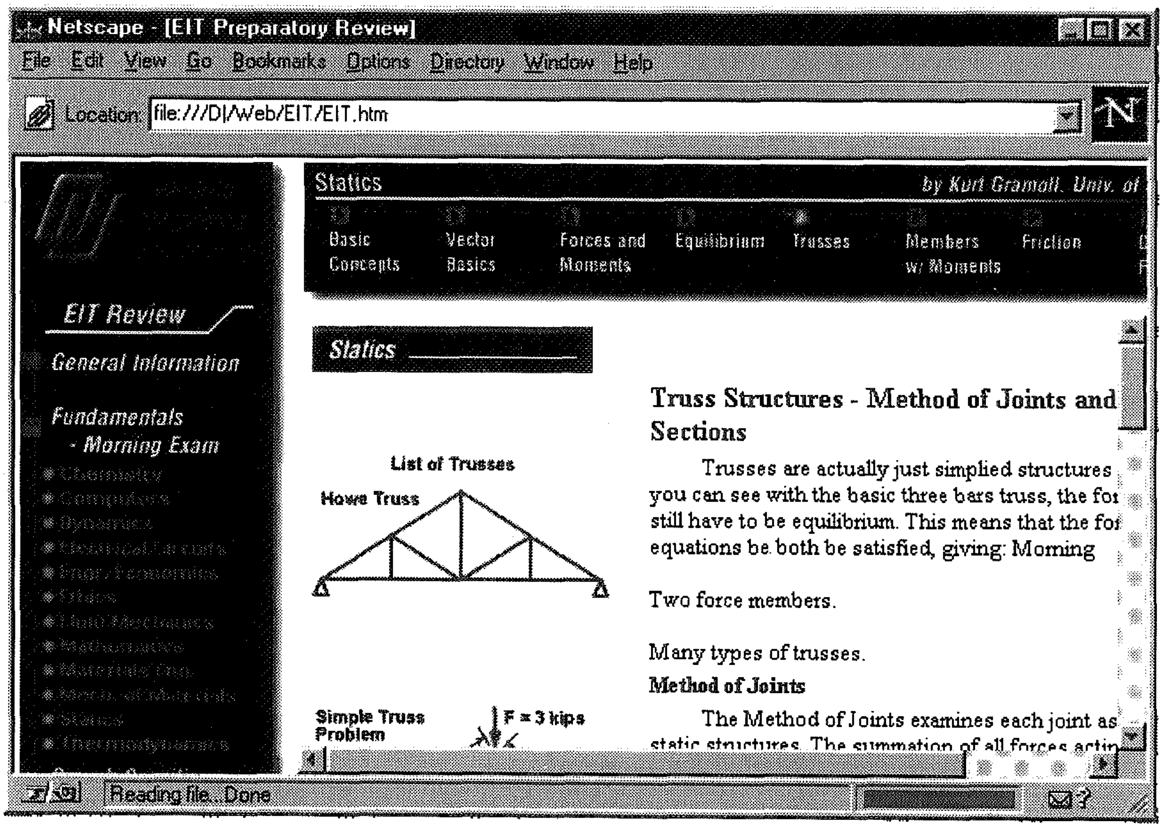
It is not enough to just give static information on a CD; new and updated material also needs to be available. This CD pushed the envelope on integrating CD-based and web-based course material. The CD can access the Internet to give the user new and updated problems to explore.



EIT Review Example and Demonstration

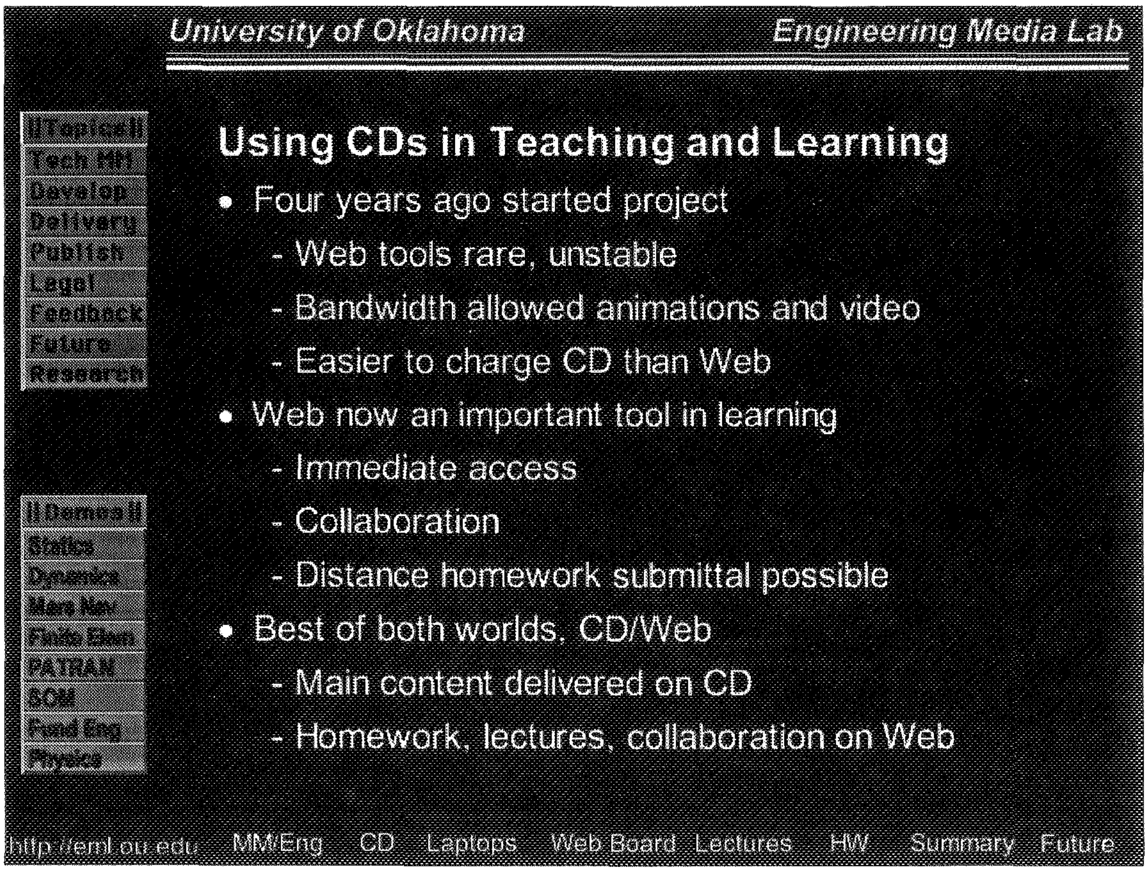
Another example of multimedia in engineering is the new web-based review site to help new engineers and practicing engineers study for the Fundamentals in Engineering exam. This exam has recently been modified and the new exam has two types of tests. The morning session covers the basics in all fields of engineering. The afternoon session concentrates on five major areas that are different for each field of engineering.

The web-based review gives fast access to current information on the test. Special animations have been developed for use on low bandwidth access to the Internet. There are also on-line tests that can be taken interactively with instant grading. The big advantage of web-based material is the ease of content delivery and updating. Currently, the site is still being developed, but it is open to the engineering public for inspection.



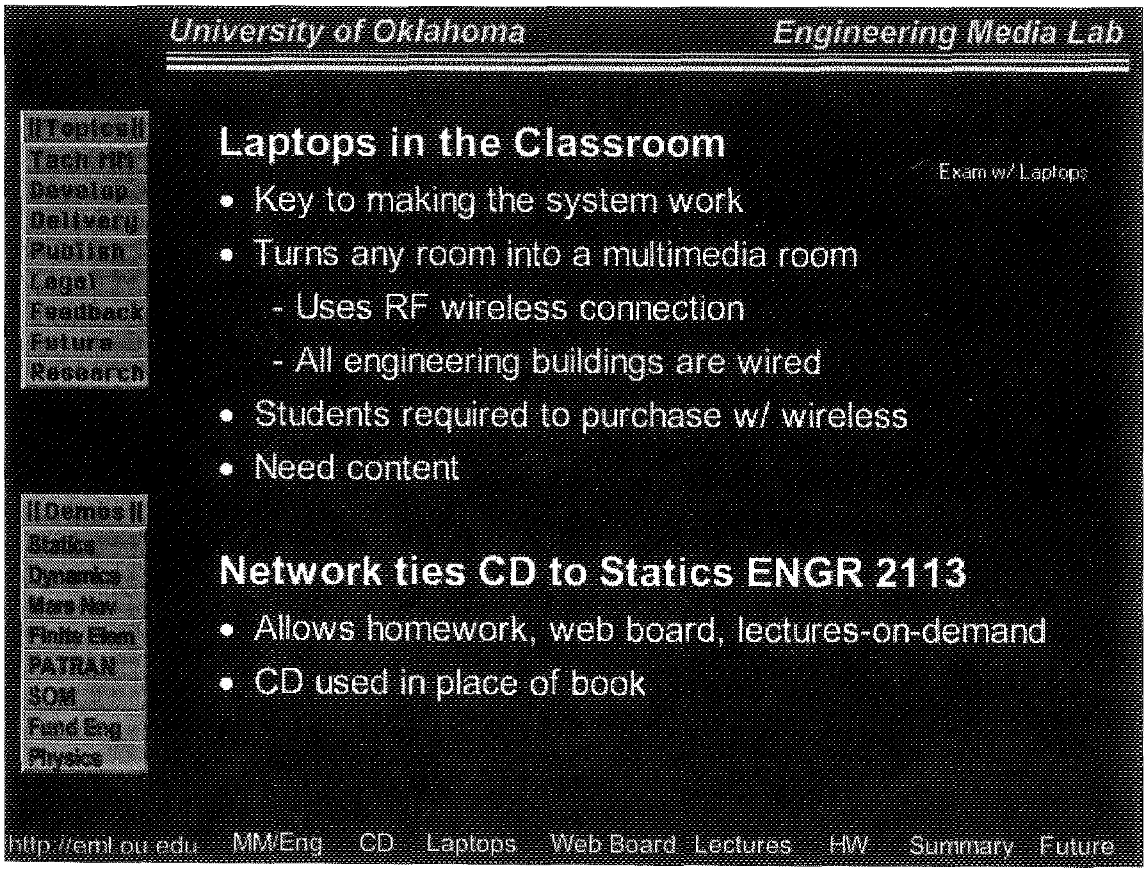
Using CD-ROMs and the Internet Together for Teaching

Now, back to the main topic of this presentation - teaching Statics using CD-ROMs, the intranet and laptops. The Statics course was first developed for CD delivery. The CD contains a complete course except for homework problems for Statics. It was originally thought that the CD would be used with a book and the book would be the source of homework problems. However, with the recent advancements in web-based learning, it is now possible to tie the CD and the web together. This gives the students both the depth of CD-based multimedia material and the current material from the web. It also allows new technology, like lectures-on-demand and web-based news groups, to be used in the course.



The Use of Laptop Computers at The University of Oklahoma

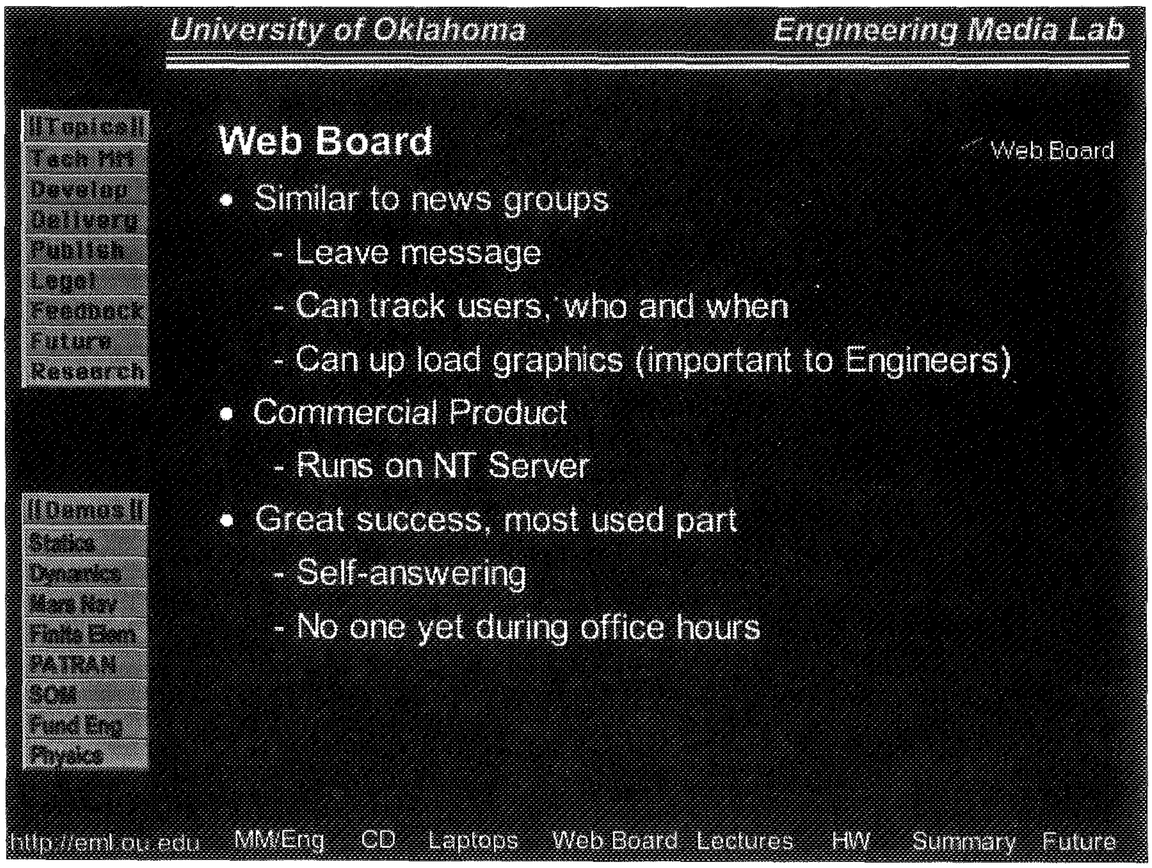
A key element in the OU Statics course was the use of laptop computers. At OU, all new incoming engineering students are required to purchase a laptop computer. These laptop computers are also connected to the network through radio frequency (RF) wireless communications. The student can receive course information such as homework or lectures anywhere in the engineering buildings. Thus, regardless if the student is in or out of the class, or just sitting in the hallway studying with classmates, he or she is connected.



News Groups

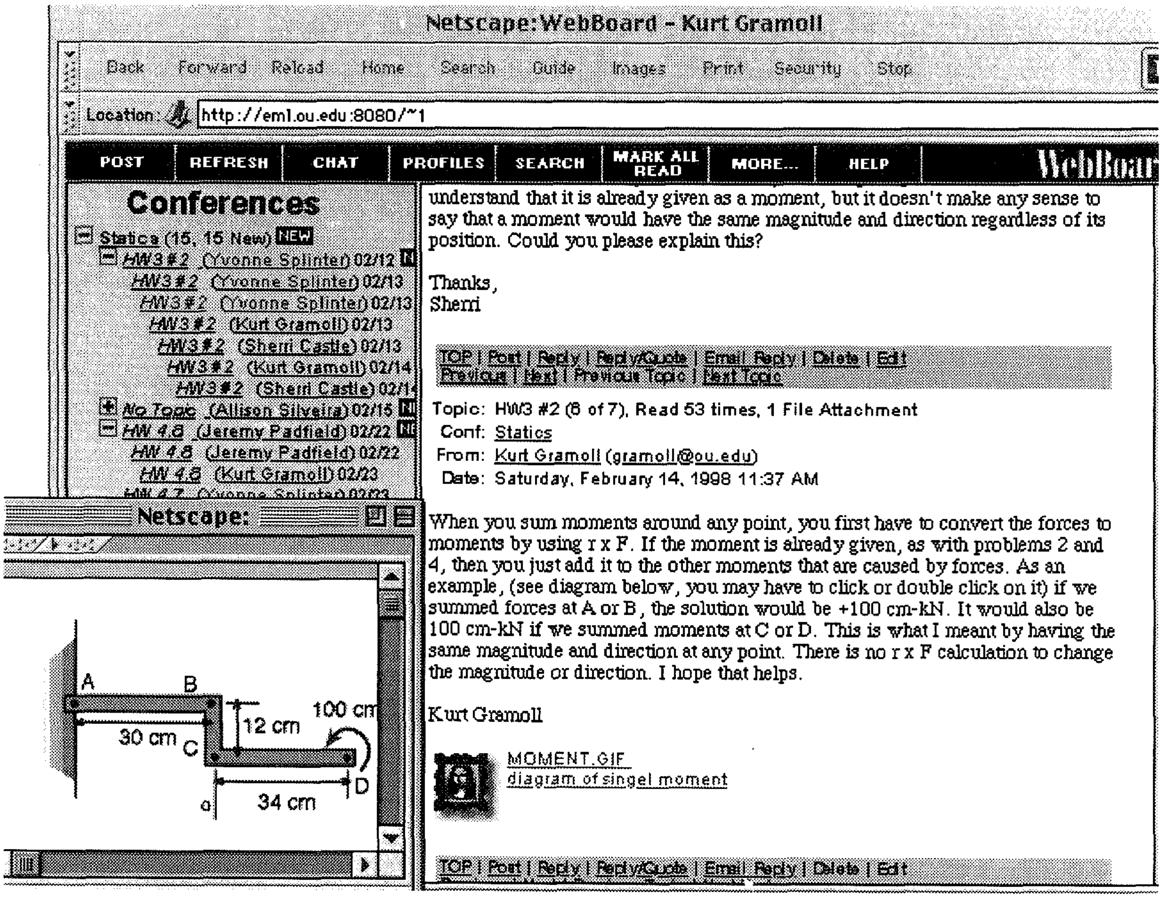
There are many ways to set up news groups for individual courses. News groups have also been around for many years but they are difficult to use for engineering courses since they cannot handle graphics. There are several new programs now available for hosting news groups that allow graphs to be posted with the text messages. One of those is Web Board by O'Reilly.

The Web Board program gave students the ability to post messages and conduct chat rooms on line. This reduced the number of students that came to the office for office hours. The Web Board was particularly useful for clarifying homework questions.



Example of the Web Board News Group

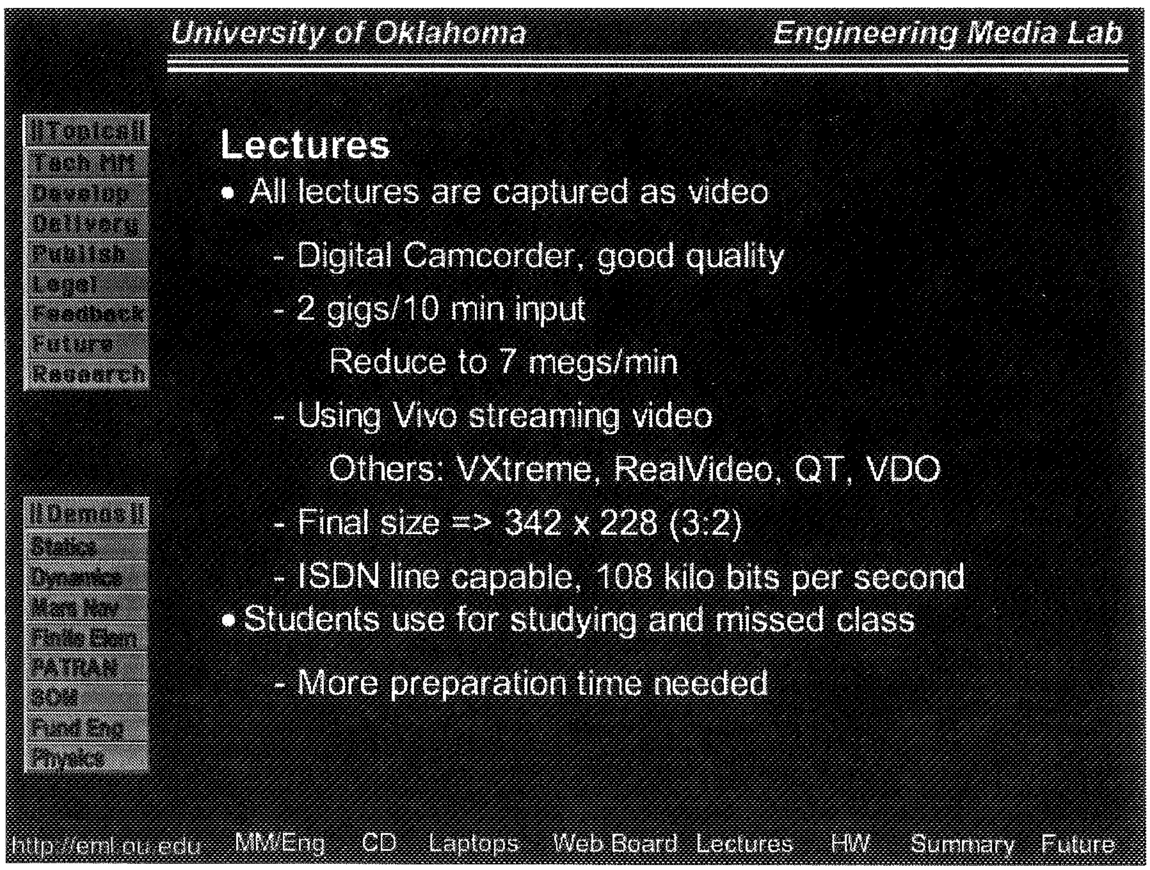
As an indication of how easy news group type software is to use, the author was able to purchase Web Board and get it running for the Statics class within a couple of days. This was with no experience with news groups. Surprisingly, the light version was inexpensive (about $70) and worked well for two courses. It monitored student usage and notified me when new messages were posted. There was no maintenance except to reinstall it when the NT server crashed.



Lectures-on-Demand for Engineering Statics

One of the greatest advantages of using the OU Intranet is the ability to delivery lectures to all students. Originally, it was planned that the lectures would be provided to students that missed class. However, the lecture-on-demand has worked so well that it is now thought possible to make these lectures available to future students in all classes.

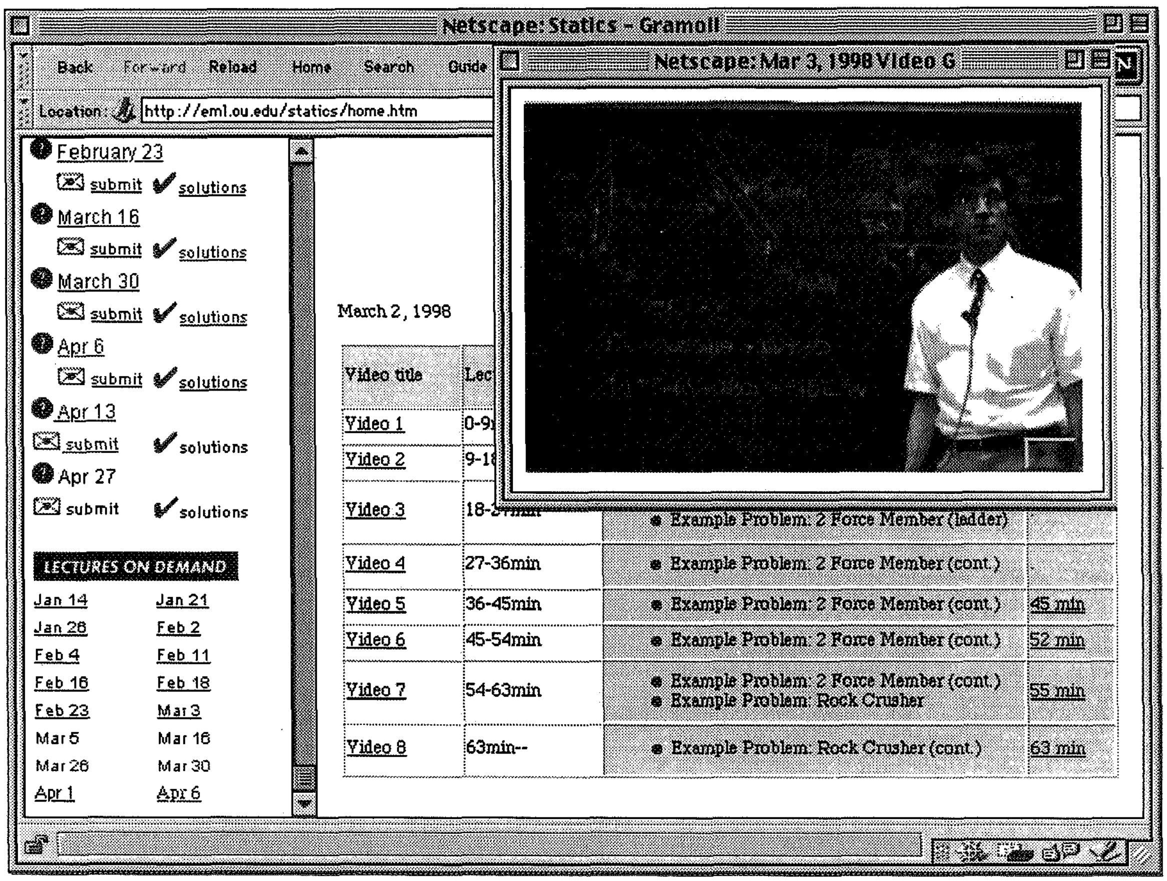
The lectures are captured using a digital camcorder. The video can be fed to a computer and served out to the Internet in real time (ten-second lag) or saved to disk. The real time delivery works well, but the image quality suffers. Thus, most lectures were taped and then later downloaded to the computer, compressed and transferred to the web server. The streaming technology used was Vivo due to its low cost and ease of use while still having high quality. Also, Vivo video files can be served off any server and any platform.



Example of Streaming Video

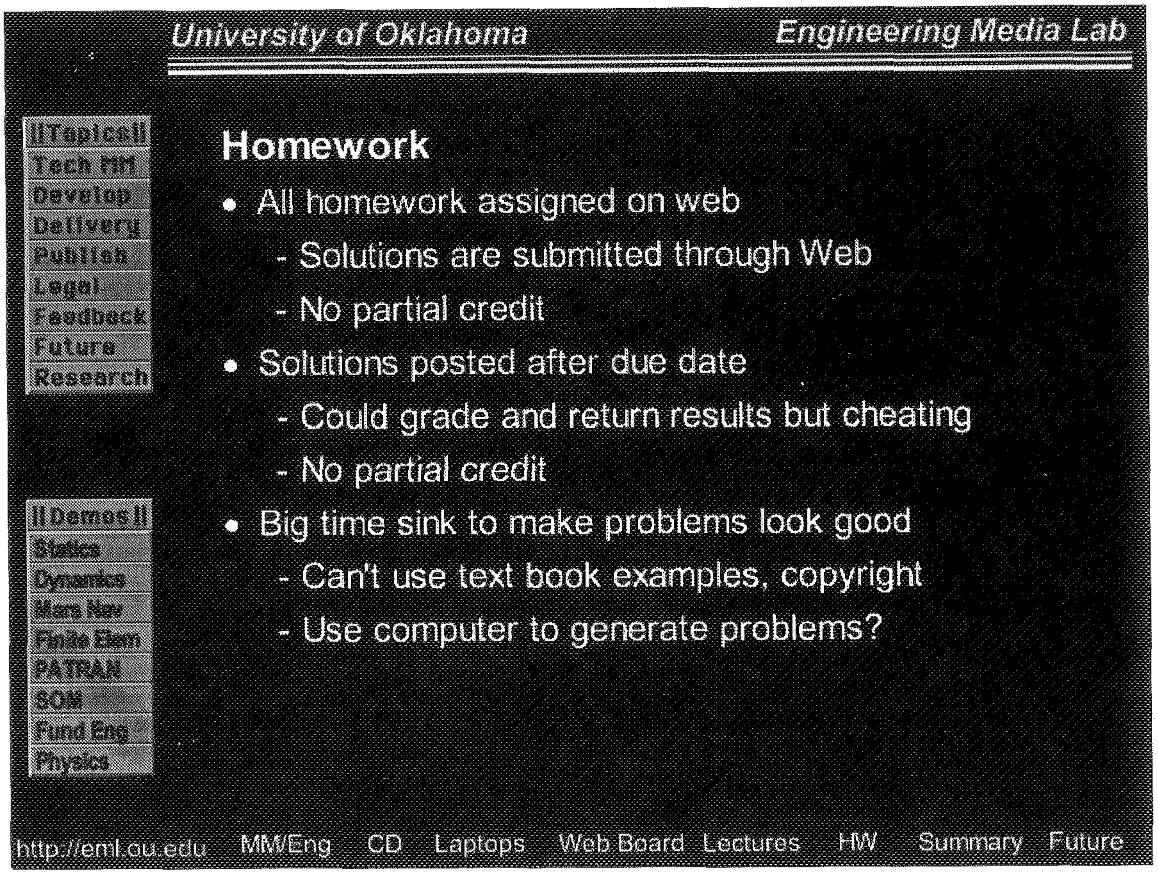
This is an actual screenshot showing the quality and size of the lectures-on-demand. Each lecture is split into approximately ten-minute segments and posted on the web. Clicking on the appropriate link accesses each segment and a new browser window comes up with the video. The video is streaming so within 5-8 seconds the information is delivered. The downside of video streaming is the lack of a slider bar to move back and forth in the movie.

You will note that the graphics are readable, but not perfect. The data rate and size was adjusted to make the video as small as possible but still readable. There is a very fine line between small data rate and usable quality video. In this case, the lectures are 342 x 228 (3:2 ratio) and are less than 100 kilobits per second. This is ISDN line capacity, which makes the worst case for the RF wireless connections that are installed on all laptop computers. Home based delivery is possible on 56.6-kb modems, but there will be pauses during the delivery of the lectures.



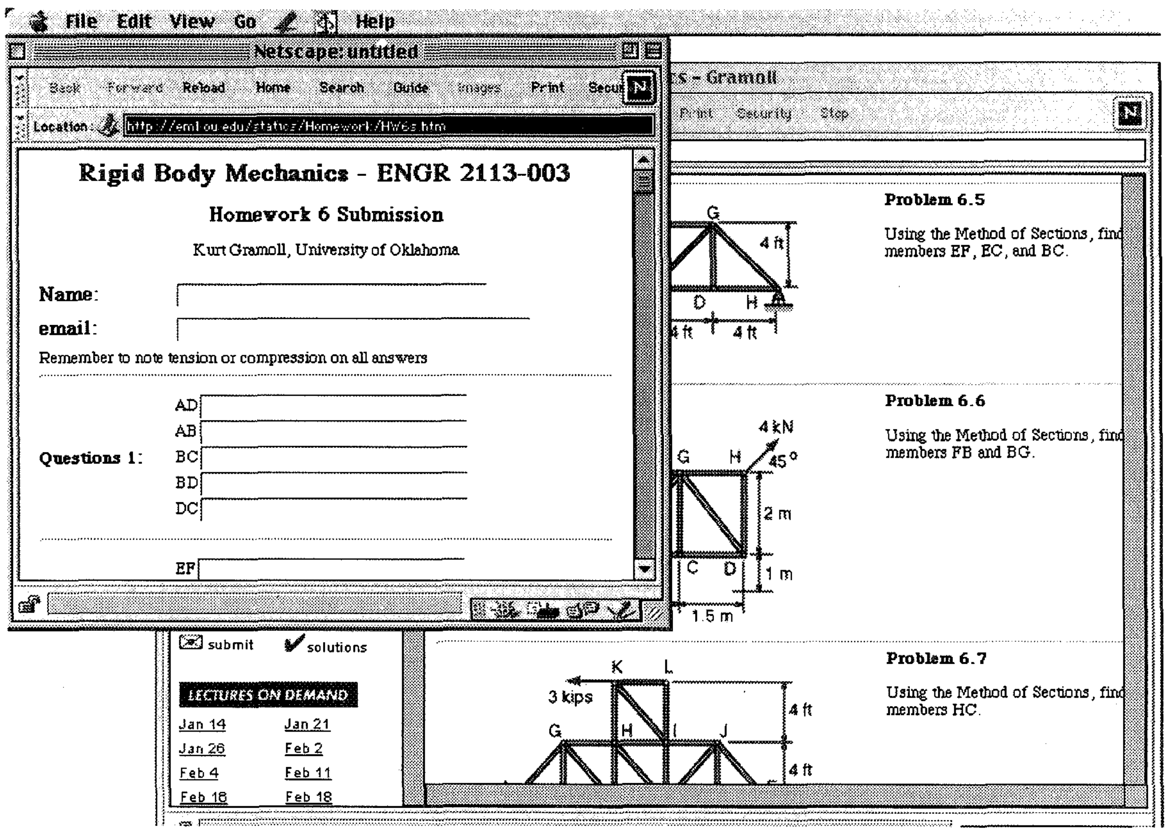
Web Based Homework

Homework was posted and submitted through the Internet. Like usual, students would generally wait until the last minute to submit homework. The submittal form (see next page) allowed students to enter only the final answer. Thus, there was no partial credit other than giving students credit for submitting the answer itself. Also, the homework was not graded interactively so students that completed the homework early would not have the answers for other students. In the future, it is hoped that the computer will be able to generate more of the homework problems and do self-grading.



Example of Homework Access and Submission

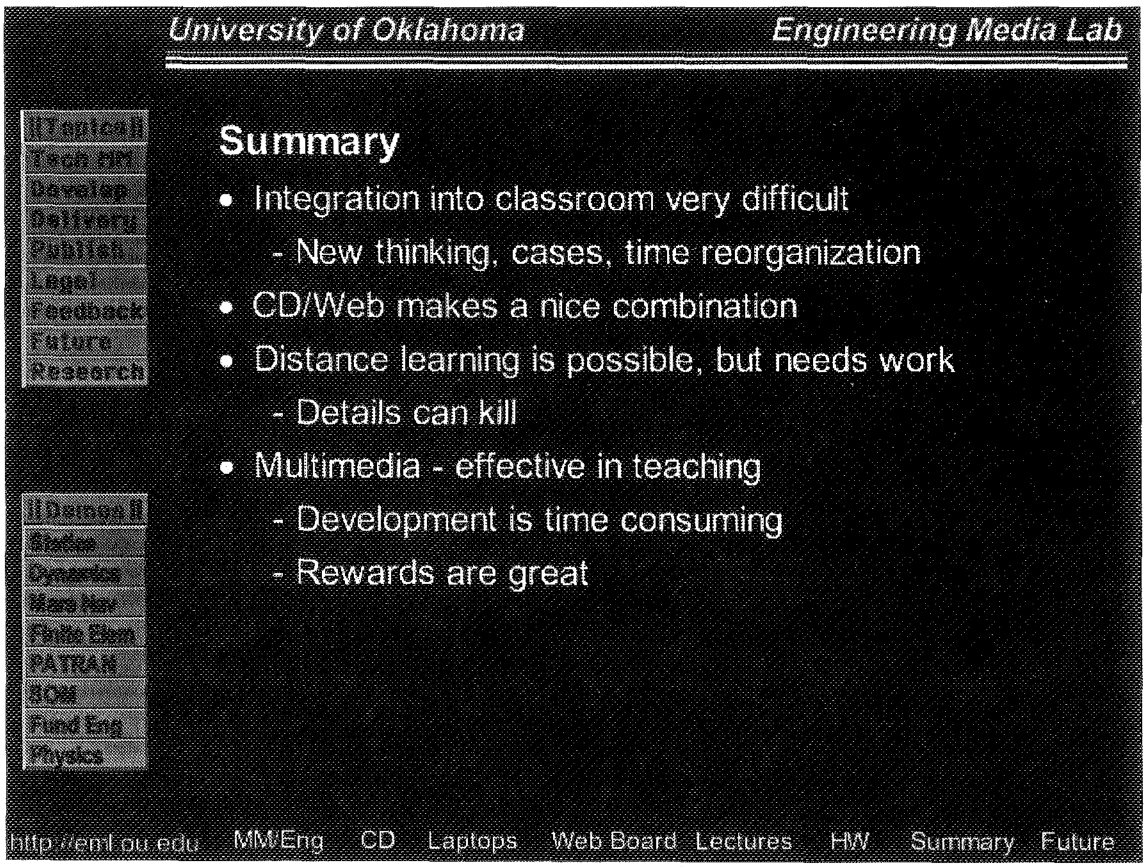
The homework is posted on the Internet for each week. The Internet allows nice color graphics, but the resolution is more restrictive than paper. This required some initial planning to insure the diagrams and graphics would be suitable for the Internet. For instance, font size and dimensions had to be adjusted to make sure that they were readable. The submittal form asked for basic answers for each problem. Generally, there were two or three parts for each question. The form was generated and submitted by using CGI scripts written in the Perl programming language.



Summary

In summary, the course has been successful, but it has taken more time than a traditional class. If time were the only consideration, it would not be worth the effort for just one class of 20-30 students. It would be useful for larger classes and ideal for campus wide teaching on the Internet. The most time was spent setting up the computers, maintaining the web server, and developing new web-based homework problems. Time was saved submitting homework through the web.

The teaching effectiveness using CDs and laptop computers was good and it is felt that the students learned more through this course than the traditional book oriented course. Material was introduced faster and basic concepts covered quicker with the use of electronic media.



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"BEST" Statics Software Project

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"BEST" Statics Software Project

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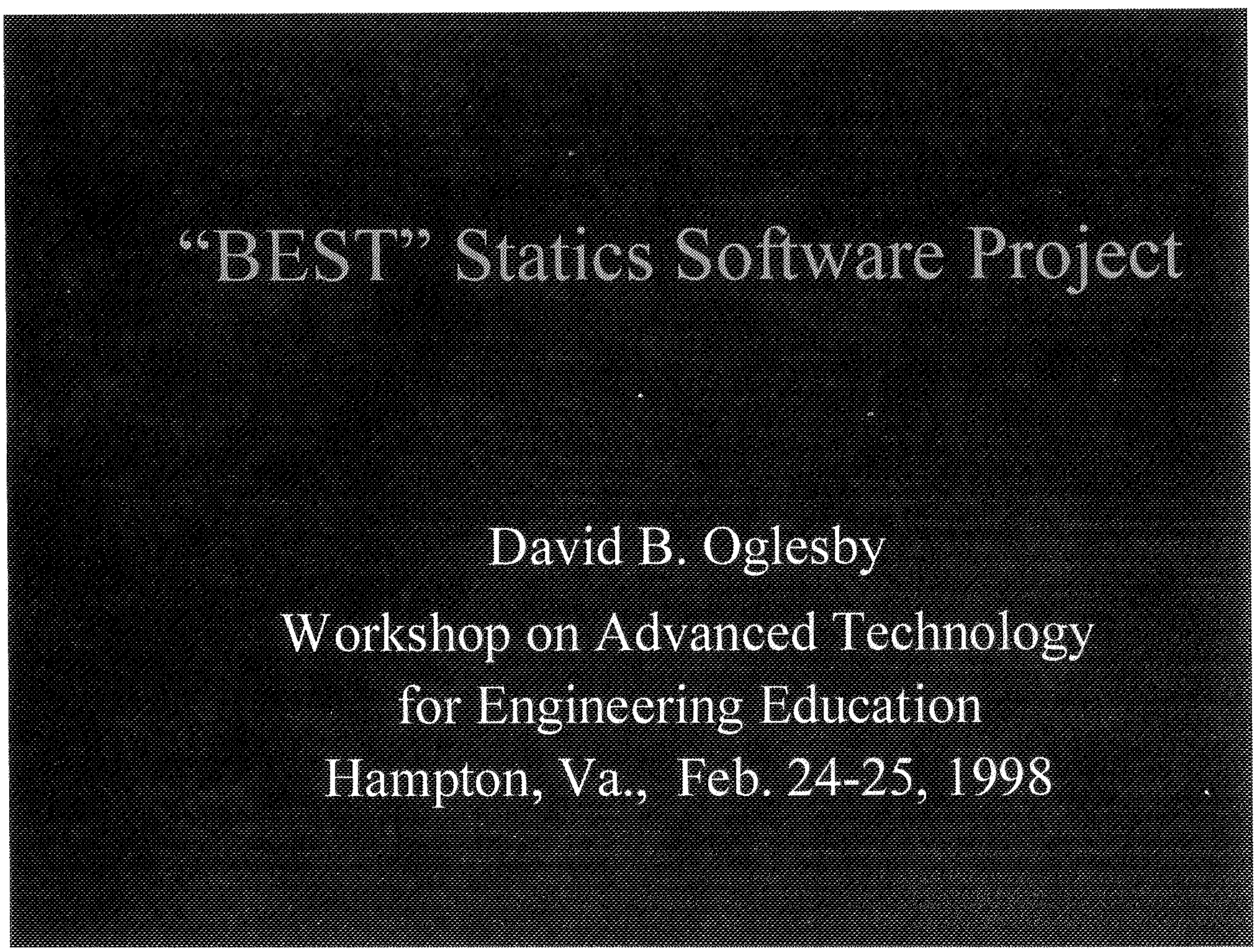
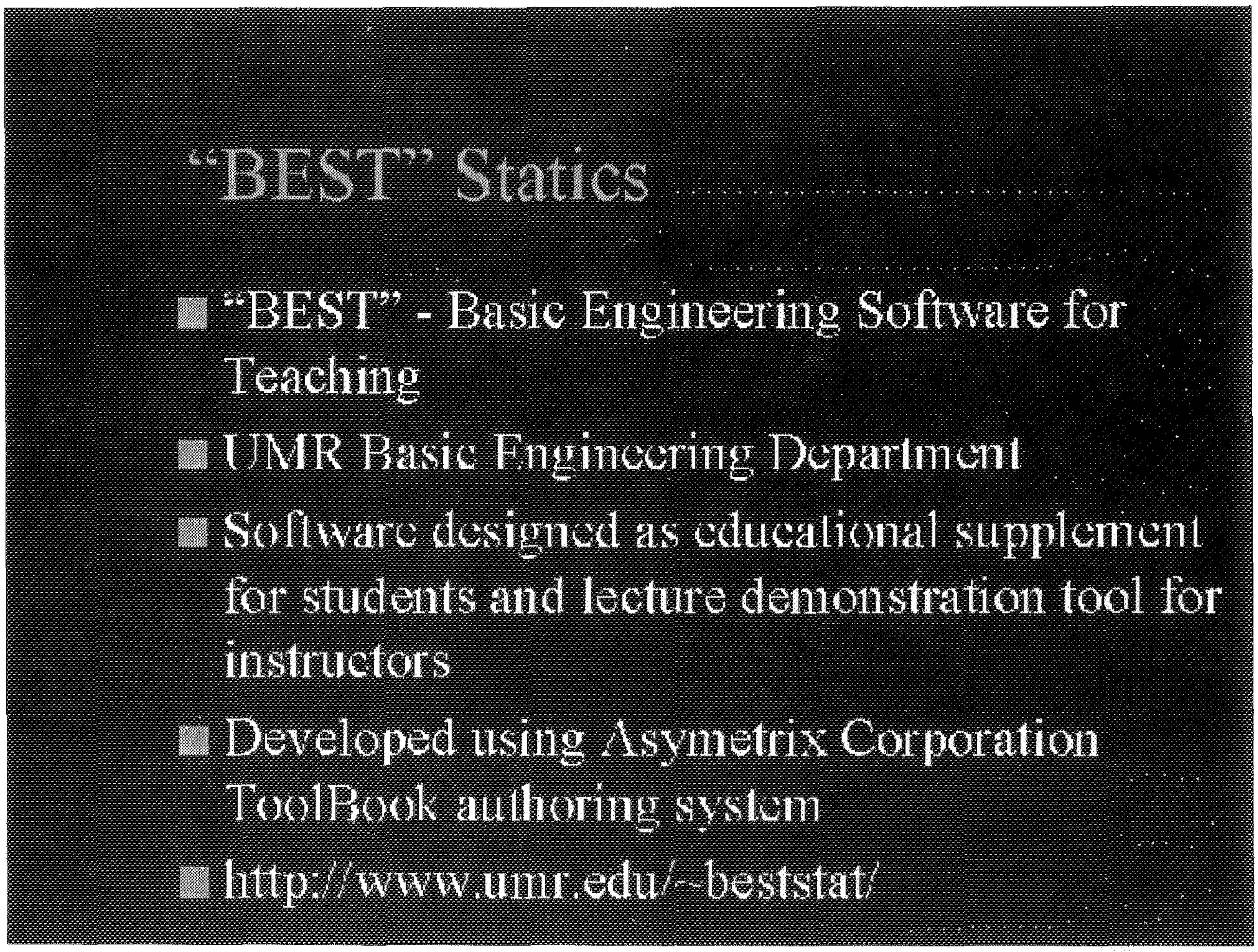
The "BEST" Statics software project began in 1995 with funding from the University of Missouri Institute for Instructional Development (IID) and the Basic Engineering Department at the University of Missouri - Rolla (UMR). The goal of the project is the production of a windows based interactive multimedia software package to facilitate the teaching and learning of engineering Statics.



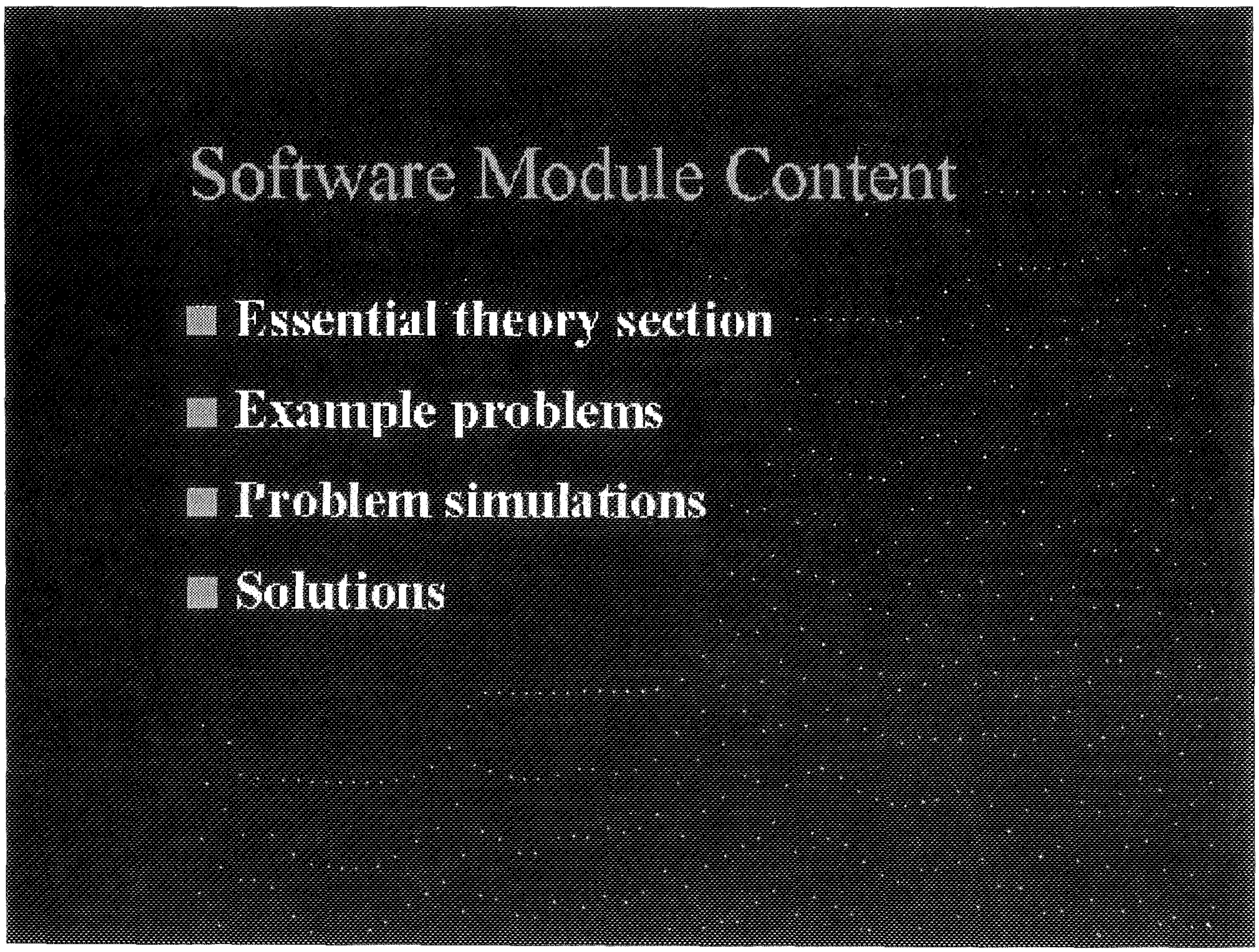
"BEST" Statics

"BEST" (Basic EngineeringSoftware for Teaching) Statics software is designed as an educational supplement to the instructor and textbook and in its current form is not intended to replace either. The software aids the student with problem visualization and problem solution formulation. It offers the instructor a classroom demonstration tool. It is being developed using Asymetrix Corporation's ToolBook authoring system. Additional descriptive information about the software is available on the web at http://www.umr.edu/~beststat/.



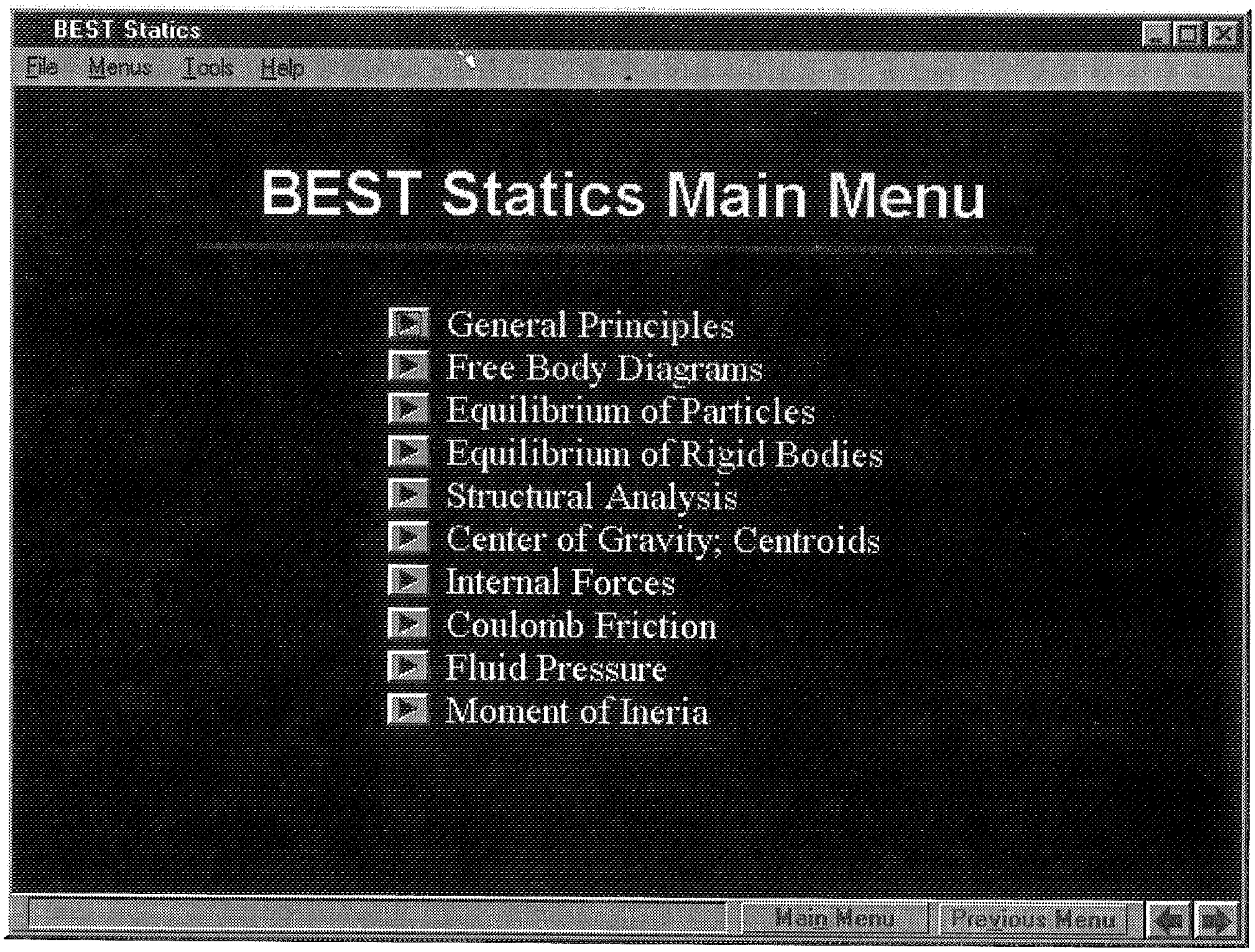
Software Module Content

The software is divided into modules with each module containing essential theory, example problems, problem simulations and simulation solutions. The theory section contains a presentation of basic theory, fundamental equations, sign conventions and general solution procedure. Detailed derivations are not included in the software. The theory section also contains example problems that illustrate the general concepts from the theory and demonstrate how the theory is applied to solve problems. The problem simulations are interactive problems that allow the user to modify input data to model a wide variety of problems and conditions. The simulations have generic solutions that place emphasis on the usage of free body diagrams and the systematic application of fundamental equations to achieve the solution.



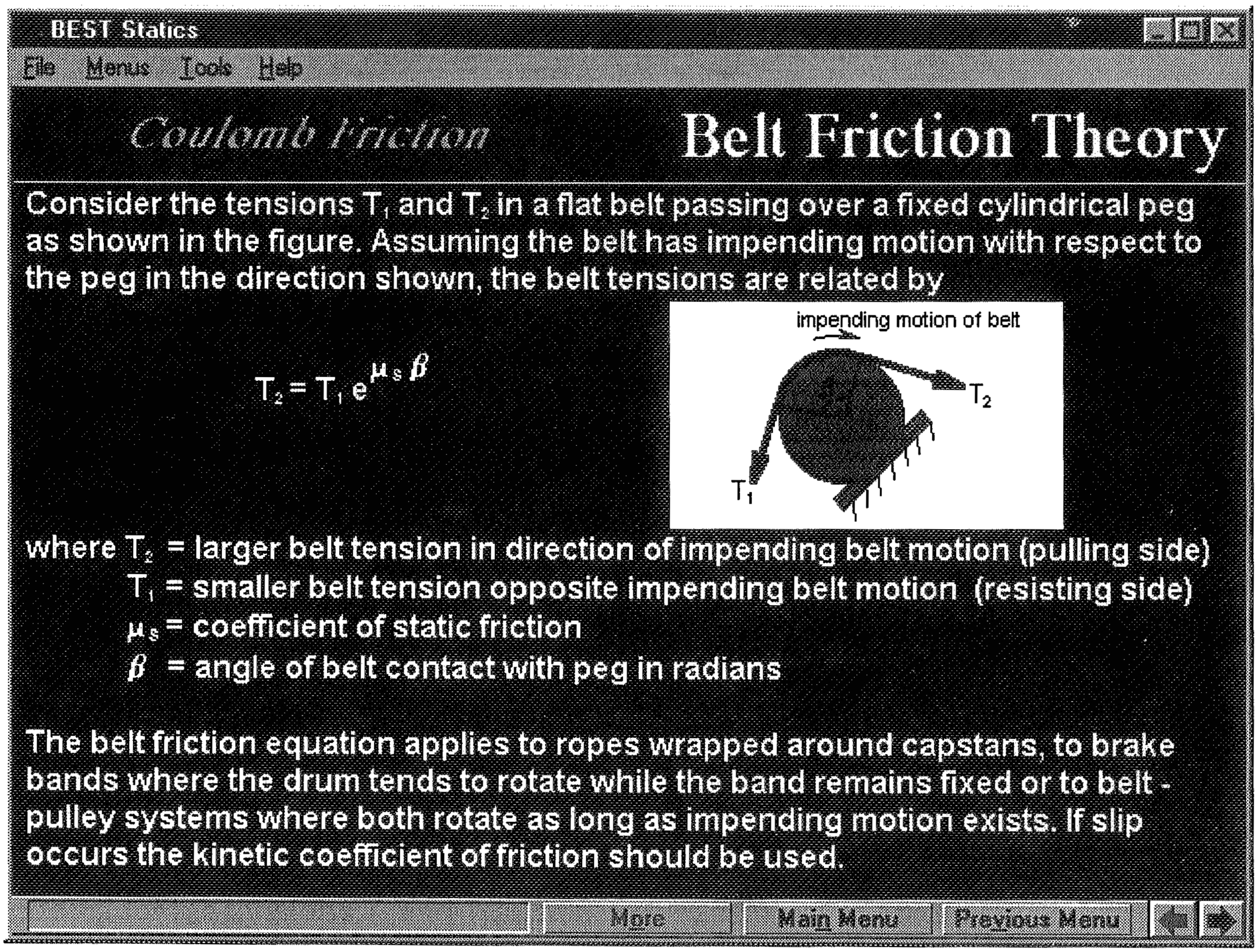
BEST Statics Main Menu

The main menu for the software shows the ten topics covered. These are the main areas covered in most sophomore level Statics courses. The following screens will demonstrate some of the material and capabilities available in the software.



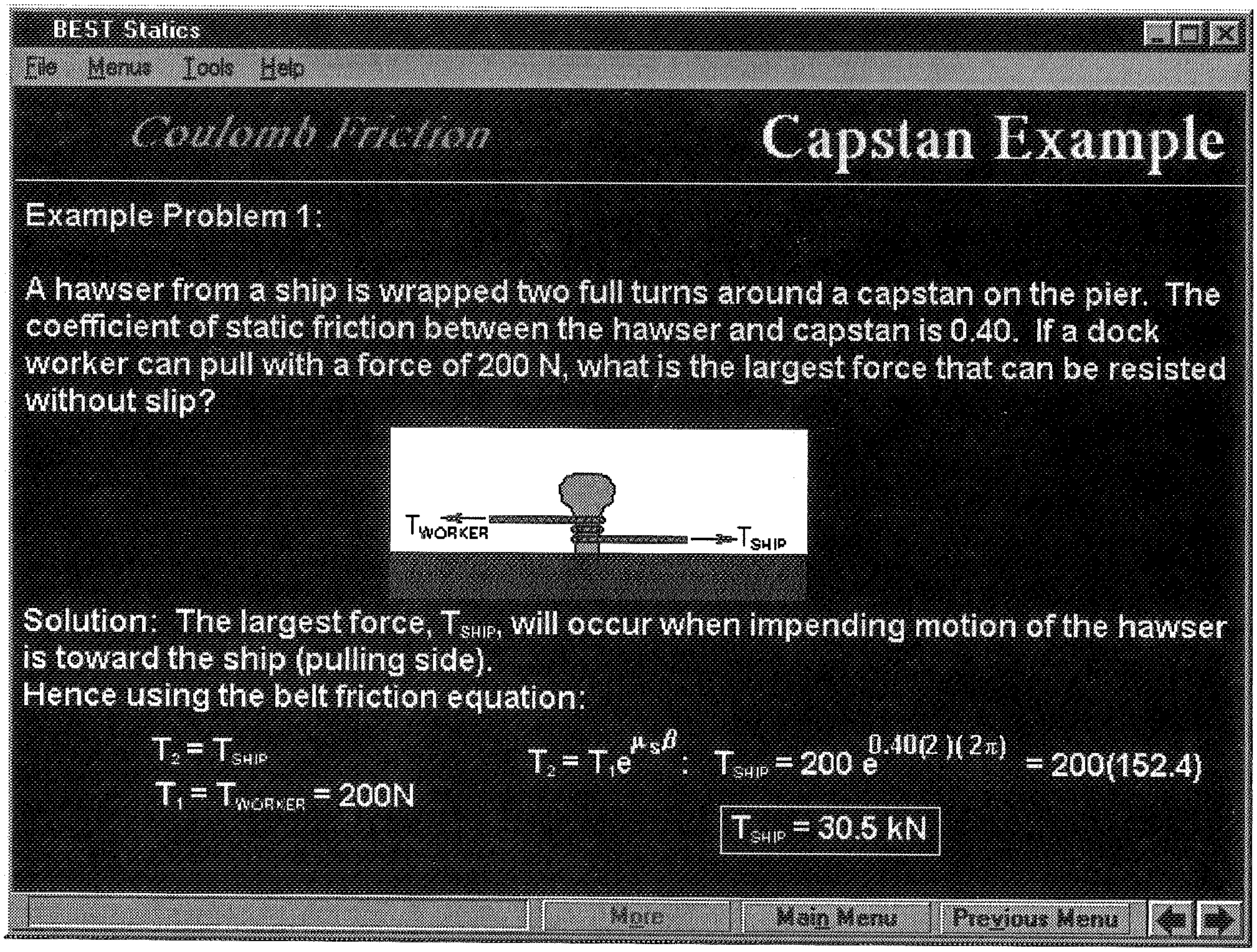
Essential Theory

Each software module contains an essential theory section that presents the basic theory, fundamental equations, sign conventions and if needed a general solution procedure for the topic. The theory screen for belt friction presenting the flat belt equation for impending motion of a flat belt relative to a peg is shown. The theory sections in general do not contain equation derivations since the software is meant to be a supplement to a textbook and instructor.



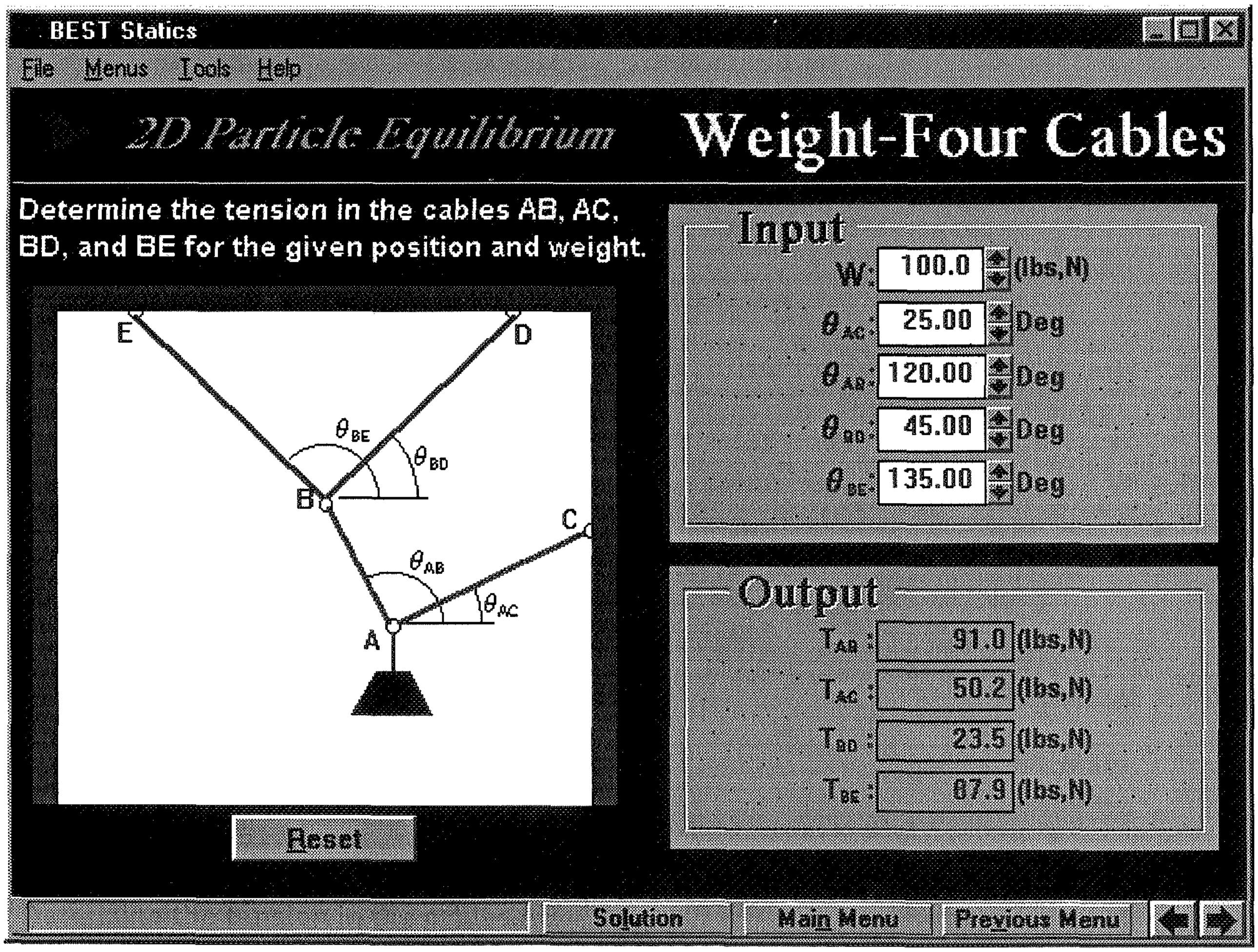
Example Problems

Each theory section also contains an example problem or problems to illustrate the concepts covered in the theory section providing the student with examples of how the theory is used in problem solution. The first example in the belt friction module, where a rope from a ship is wrapped around a capstan, is shown. The problem determines how much force can be resisted by a dockworker knowing the force he can apply to a rope, the coefficient of static friction and the number of turns the rope is wrapped around the capstan.



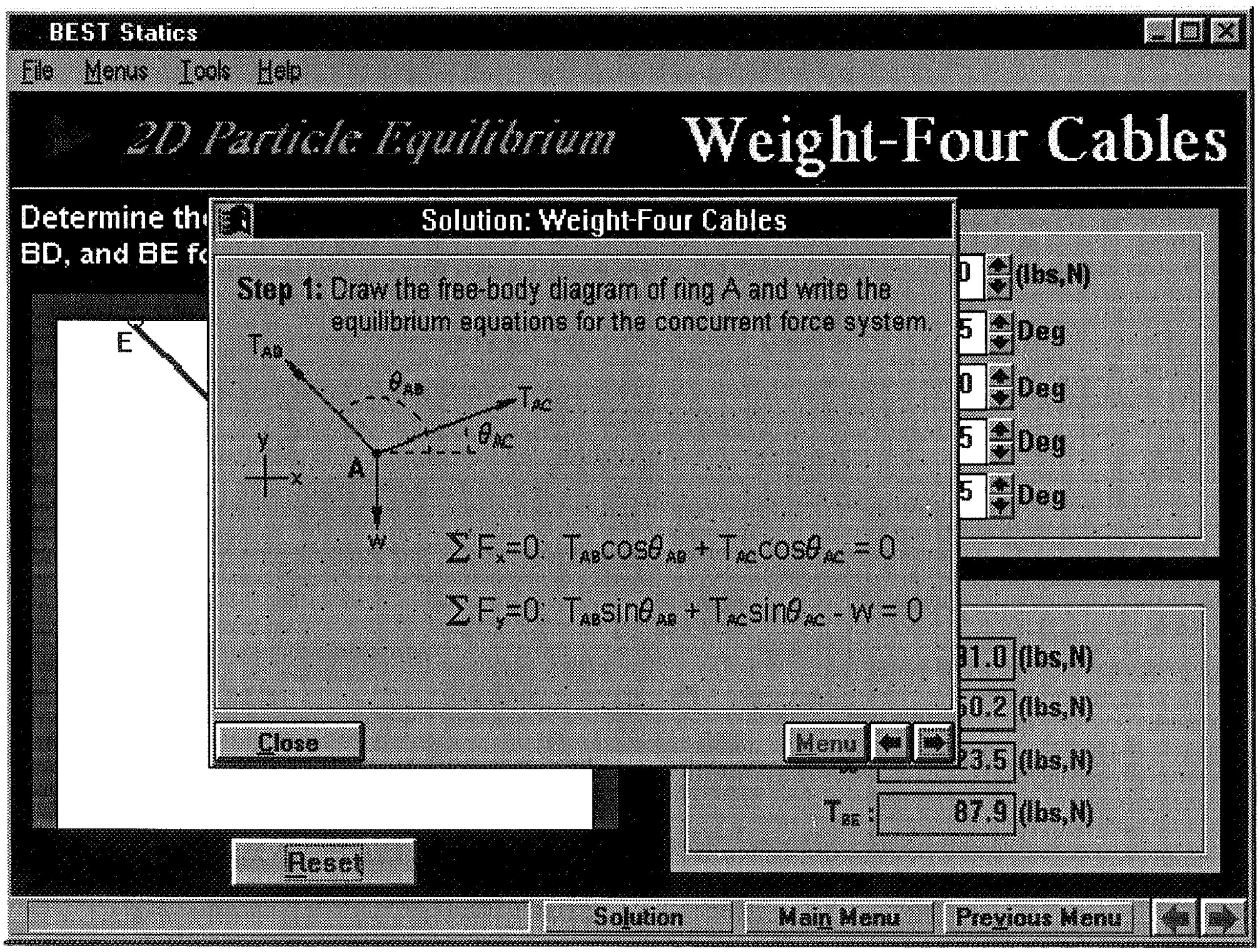
Problem Simulation(s)

The 2D Particle Equilibrium Module is used to illustrate one of the simulation problems. The figure shows a simulation where four cables are used to support a weight. The simulation allows the user to input (within ranges) the cable angles and the magnitude of the weight. Clicking the Reset button will redraw the cable configuration and give the cable tensions. Immediate error feedback is provided if the user attempts certain cable arrangements. For example, if the user attempts to make both cables AB and AC or BD and BE horizontal, the program will show an error viewer and explain that there must be a vertical component to carry the vertical system loading. Likewise an error viewer will appear is the user attempts to input an unbalanced horizontal cable configuration.



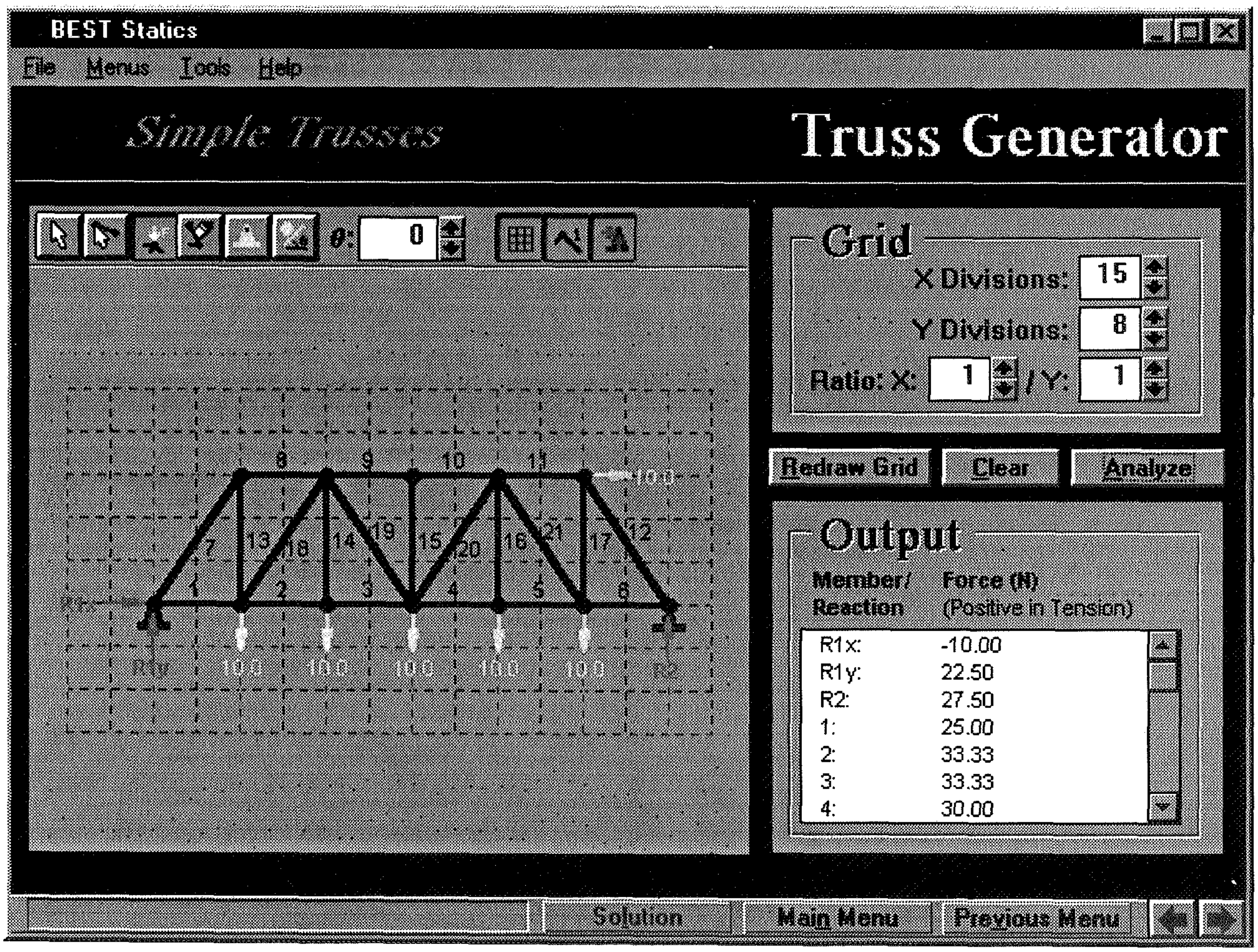
Problem Simulation Solution

Each problem simulation has a generic solution that may be opened in a viewer by clicking on the Solution button on the navigation toolbar. The viewer, when opened, can be moved around the screen to allow the user to view the problem simulation input if desired. Several screens are generally needed to cover all of the solution information. The figure shows the second screen of the solution viewer for the Weight-Four Cable simulation showing the first of the free body diagrams and related equilibrium equations used in solving the problem. Clicking on the navigation arrows will show additional screens of the solution.

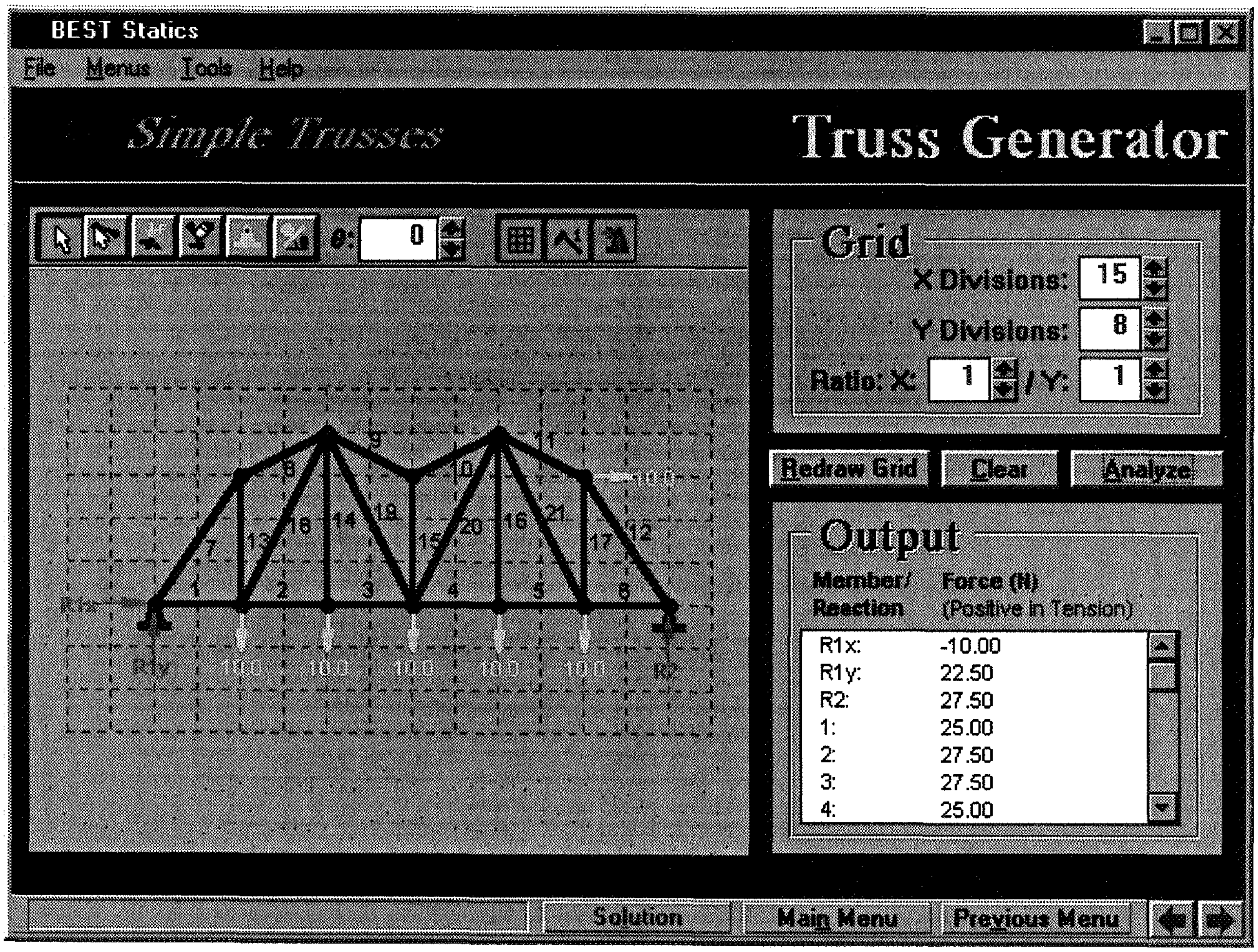


Structural Analysis

This structural analysis section contains the planar truss, the frame and the machine modules. The Planar Truss module allows the user to choose and scale a grid in two dimensional space, to use a menu toolbar to determine the support locations on the grid, and to add joints and members to create a simple truss. The software allows the user to delete members and joints or to move a joint in the truss and have the attached members automatically move to the new joint location. This feature facilitates making corrections and/or modifications to the basic layout of a truss and will allow a user to investigate the effect on the forces in the members when modifying the basic configuration of the truss. Shown is the basic grid, members, joints, supports and loads for a simple truss that has been analyzed. Once the truss is generated and loading applied to the joints, the truss is analyzed to determine the force in each member and the reactions at the supports.

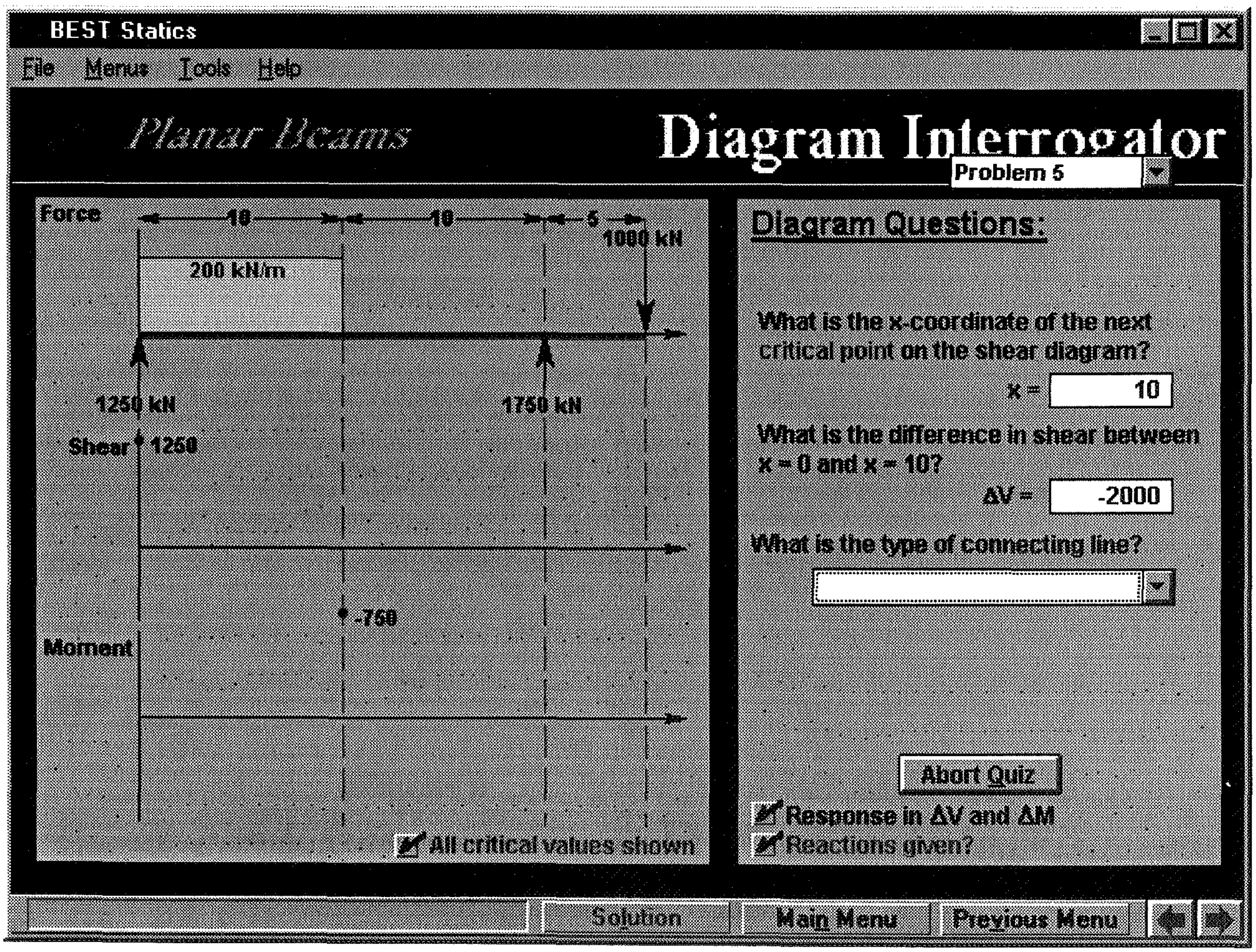


The truss shown here is identical to the one in the previous figure except that two joints on the top chord were moved to new positions by clicking on the pointer on the menu toolbar and then draggingthe joints to new locations. The software then automatically moved the connecting members to their correct locations so the new truss could be analyzed by clicking on the Analyze button. The ease of modifying the truss geometry and loading allows the student to pursue "what if" type questions to discover the effect of changes on member forces.



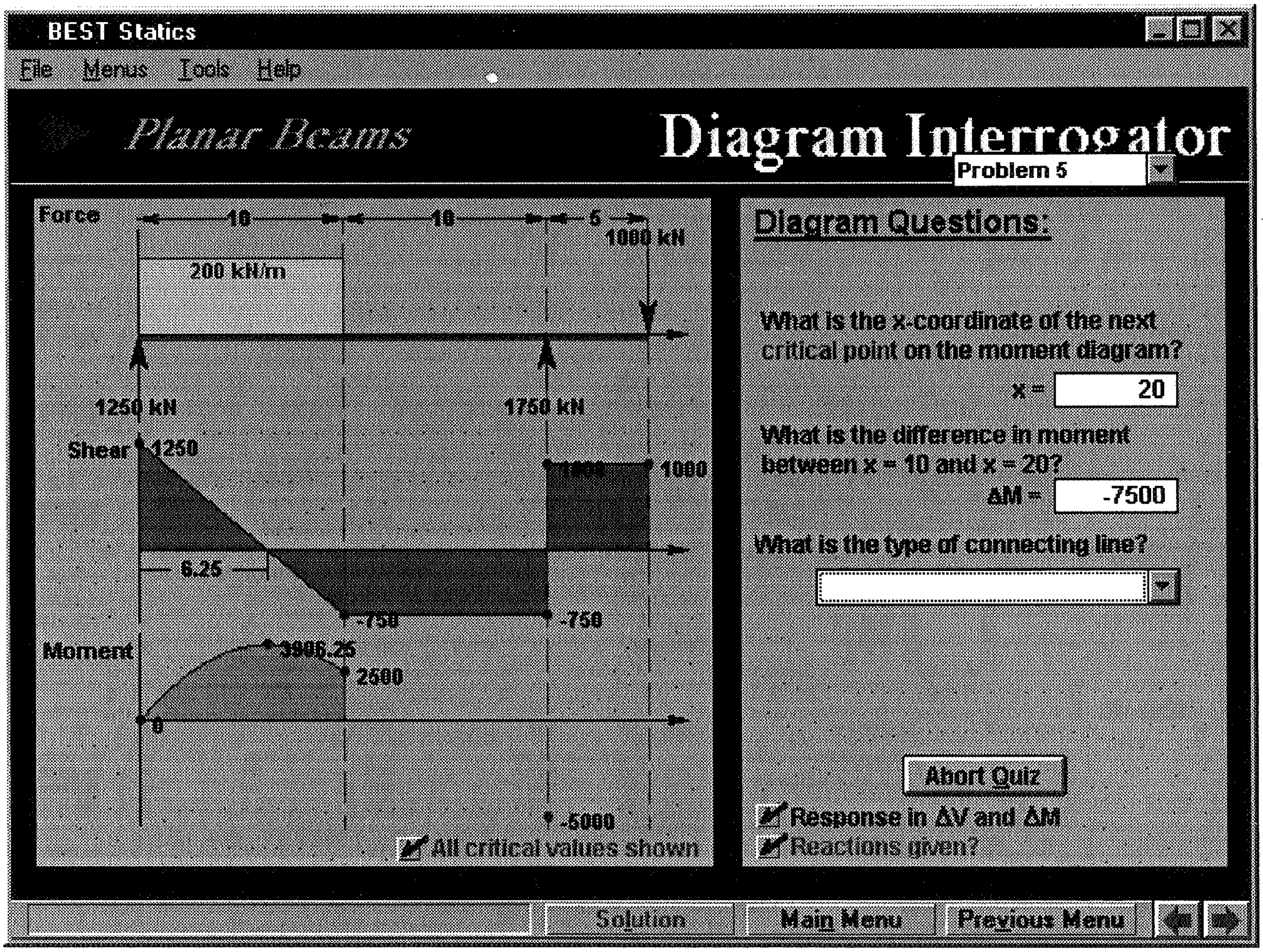
Internal Forces

This section currently consists of the planar beam module. An additional module containing general coverage of internal forces is planned. The planar beam module allows the user to investigate the effect of transverse loading on planar beams. In addition to essential theory, there are thirty seven interactive beam cases available where the user is able to determine the support reactions, write the equations for shear force and bending moment as functions of position in the beam, and/or sketch the internal shear force and bending moment diagrams. In each case the user is interactively led through the necessary steps and is given immediate feedback when an incorrect choice or answer is given. The figure shows the shear and bending moment Diagram Interrogator being used to generate the shear diagram for load case 5. This figure shows the loading and the beginning steps of constructing the shear diagram. The interactive nature of the interrogator is shown by the questions in the right frame, which must be answered by the user. When correctly answered the software draws the diagrams. If incorrectly answered the user is asked to try again.



Internal Forces (Cont'd.)

This figure shows the Beam Interrogator being used to construct the moment diagram. The shear diagram is complete and the right frame shows the questions pertaining to the construction of the moment diagram for the third region of the beam. The next step is for the user to click on the drop down menu and pick the type of connecting line to be drawn between the two points on the diagram. If not linear the software will ask for additional shape information. When correct the curve is drawn.



Internal Forces (Cont'd.)

The completed shear force and bending moment diagrams for load case 5 are shown. The user has successfully completed the diagrams and can pick another load case from the drop down menu or return to the main menu or to the previous menu.

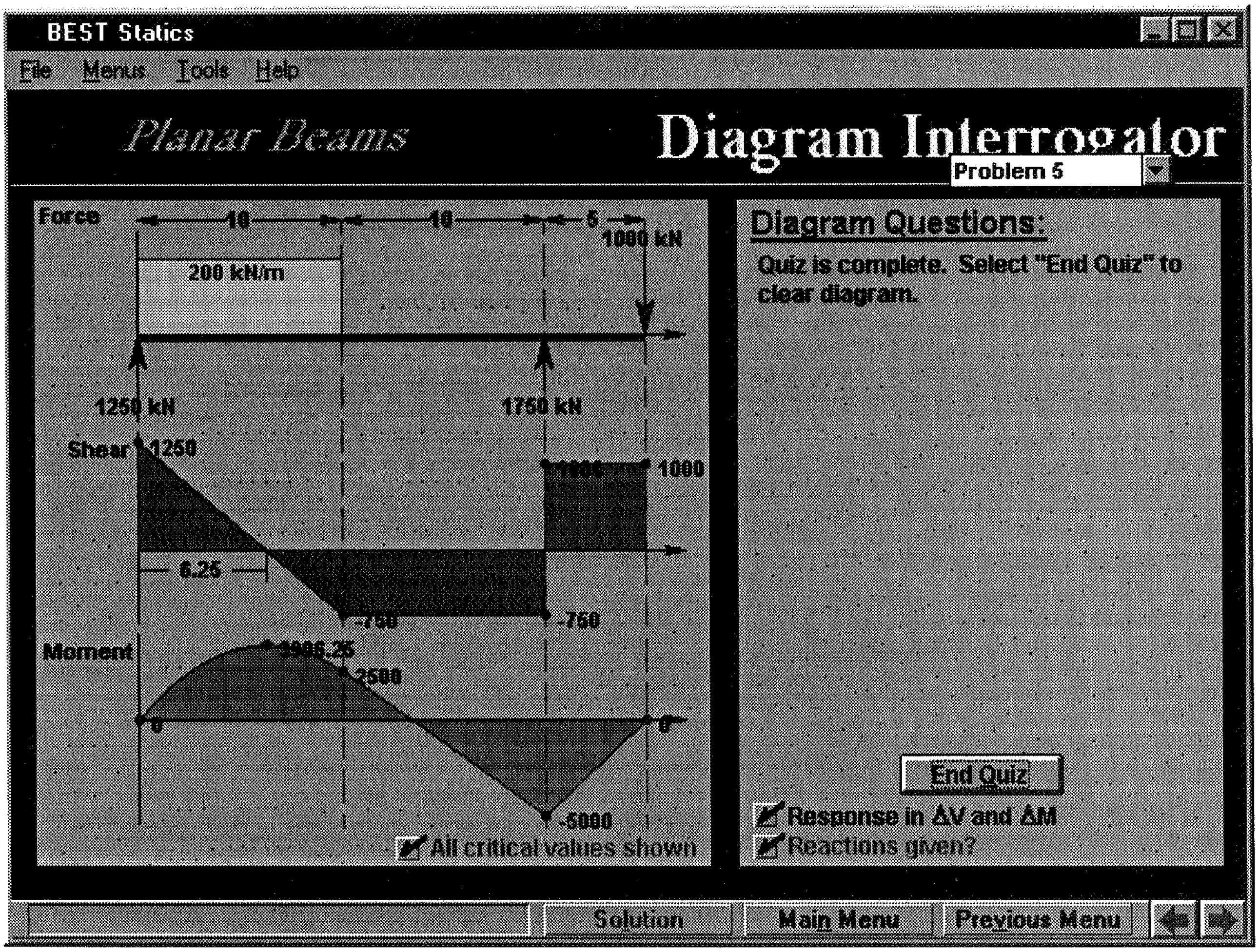


Diagram Generator

In addition to the thirty seven cases available in the Beam Interrogator, the user is able to use the Diagram Generator to input a simply supported or cantilever beam of their own design. Simply supported beams with or without overhangs and cantilever (left or right end) beams with up to ten loads (concentrated, distributed or couple moment) can be handled. Mouse clicking and dragging to a new position can move the simple supports. Clicking on Refresh Diagrams causes the software to determine the shear force and bending moment diagrams and equations as a function of position for the beam. Shown is an example where the Diagram Generator was employed to generate the diagrams for a user input data set.

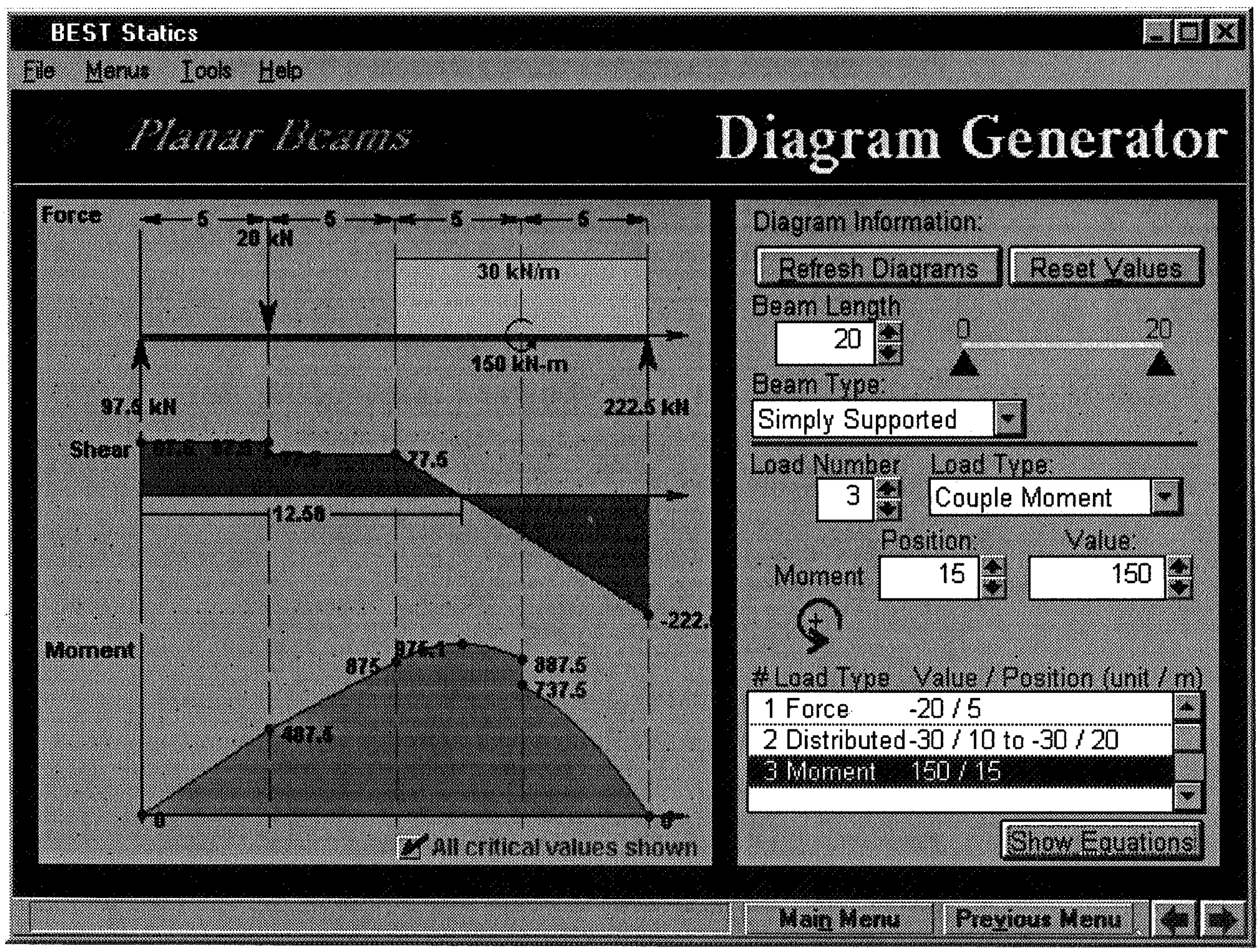
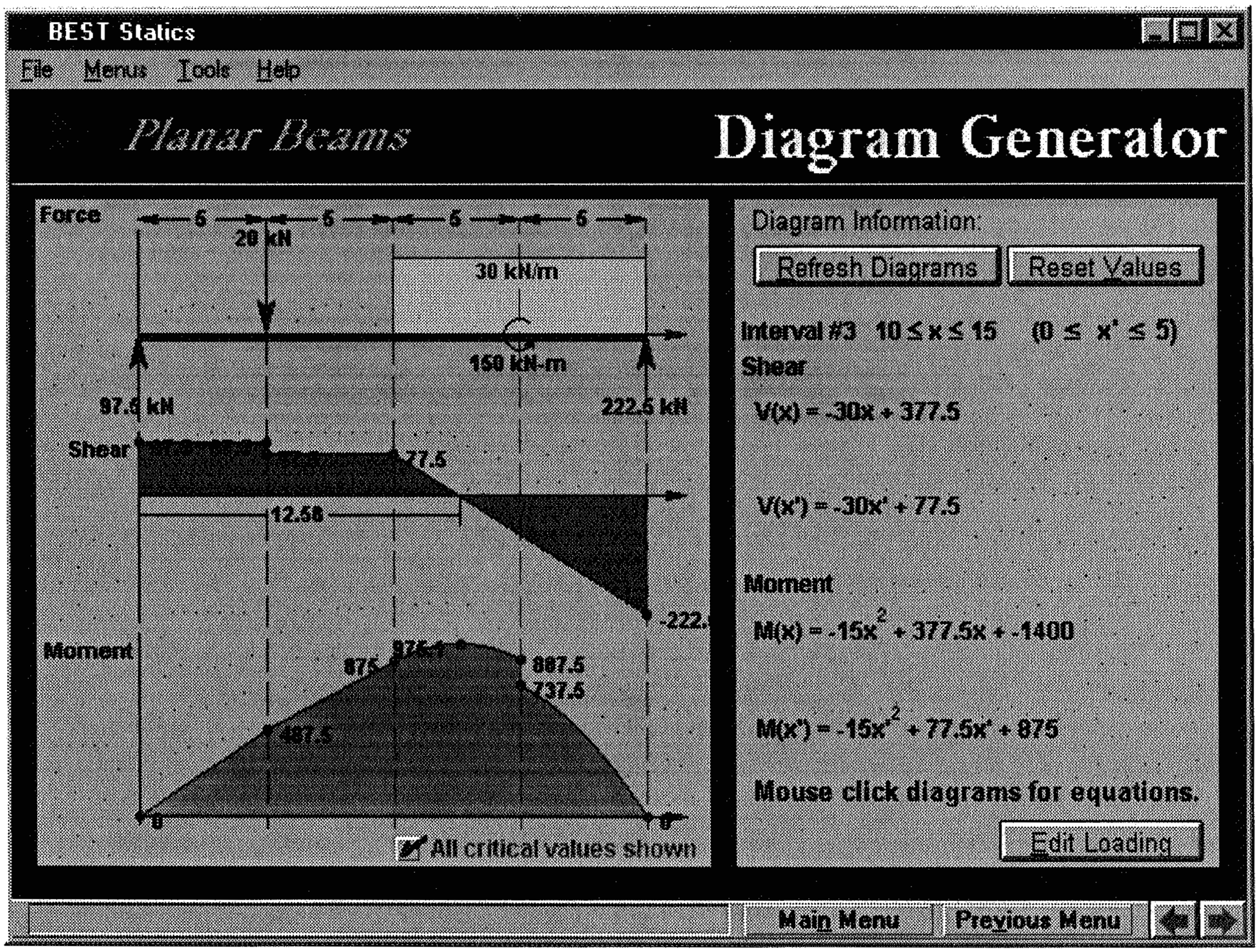


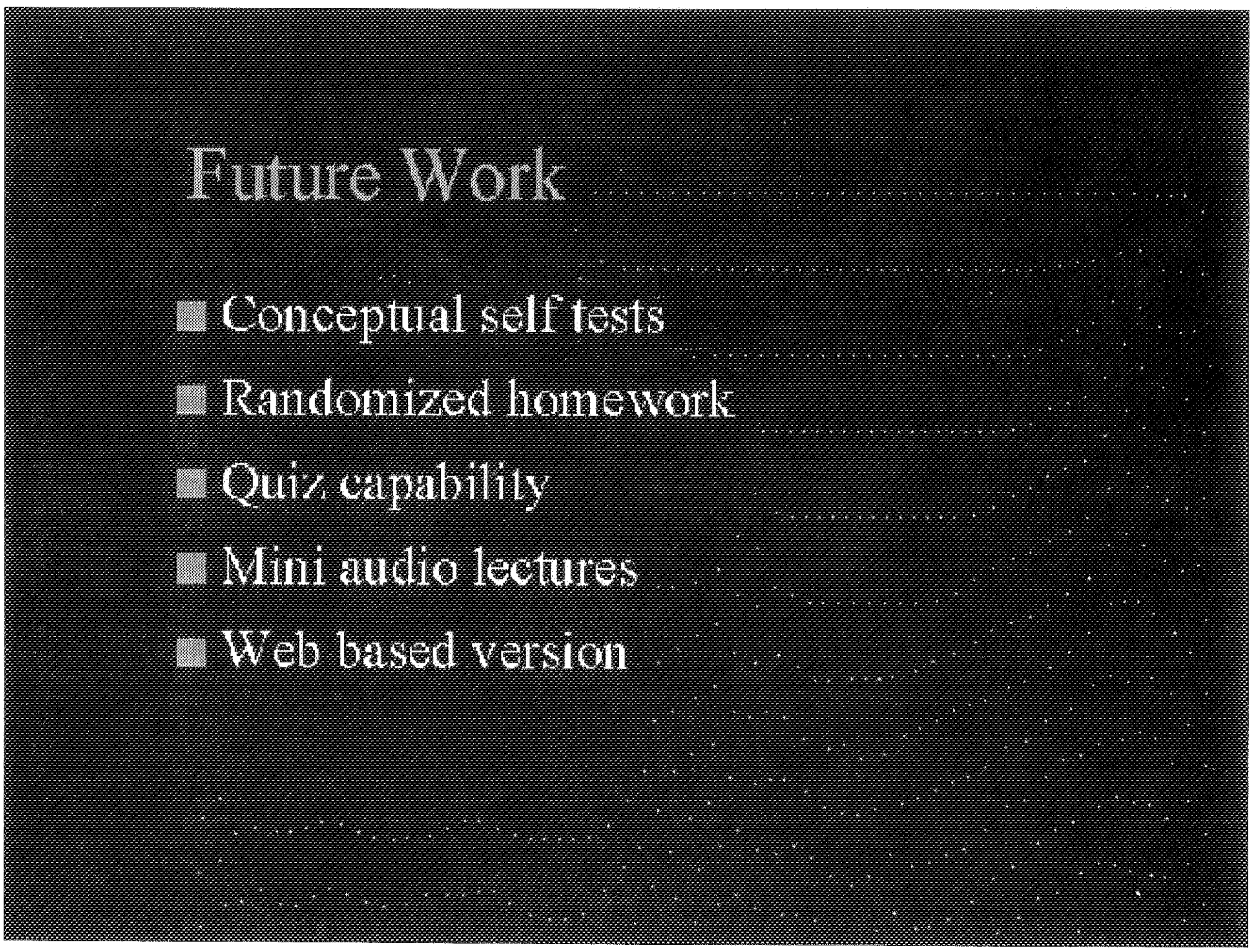
Diagram Generator (Cont'd.)

Clicking on the Show Equations button on the Diagram Generator after the diagrams are drawn will open a viewer in the right frame that shows the shear force and bending moment equations for each interval of the loading. Shown are the results for the third interval in the beam. Mouse clicking within an interval on the shear or moment diagram will show the equations for that interval in terms of x measured from the beginning of the beam or x' measured from the beginning of the interval.



Future Work

The sample modules included in this presentation are representative of the modules currently incorporated in the "BEST" Statics software. Future work will be to include various additional features: conceptual true/false or multiple choice self tests that quiz on the basic concepts and give the student immediate feedback, randomized homework problems which are automatically graded with the grades recorded for the instructor with the student given feedback on his work, quiz or test capability allowing the instructor to select problems for quizzes, audio mini lectures covering the theory allowing the student to listen and/or read the theory material, and to place some or all of the software on the web to increase availability and allow easier distance education usage.



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Teaching Modules for Heat Transfer

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University of Virginia
Charlottesville, VA

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Teaching Modules for Heat Transfer

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Workshop on Advanced Technology for Engineering Education
Peninsula Graduate Engineering Center
Hampton, VA
February 24-25, 1998

Background

The heat transfer modules discussed in this presentation stem very directly from my teaching assignments and research experience over the last decade. In particular, the experience of teaching a graduate Computational Fluid Dynamics (CFD) course regularly through Virginia's Commonwealth Graduate Engineering Program (CGEP) on television got me interested in the use of computer graphics in instruction. Unless you take very deliberate action when you teach on TV, the camera is either on you in a blue shirt or on your hand writing on a blue pad for 75 minutes straight. In order to break up the monotony a bit, I began to make little demonstrations of numerical principles and applications that I could run on the PC in the studio. Subsequently, I got very involved in the development of technology-equipped classrooms for local, non-televised courses. We have built two technology-equipped lecture rooms over the last ten years, and in January we opened three studio classrooms in our building where we can use these materials.

Background

- Teaching Experience
  - » CFD, HT, Computer Graphics, Fortran
- Televised Teaching - Virginia's GCEP
- Development of High-Tech Classrooms - 1986 - present
  - » Lecture Rooms - 1990, 1994
  - » Three Studio Classrooms - 1998

Background (Cont'd.)

Since we have been able to at least project computer graphics from an instructor console since 1990, many of these modules have been improved upon for nearly a decade. In many cases when it was clear that students did not understand the graphical presentation, the problem was rectified within a matter of a few hours.

The University started its faculty development program, which is known as the Teaching and Technology Initiative, in 1995 as a joint program of the V.P. for Information Technology and the Office of the Provost. That initiative provided the support to develop modern Windows-based graphical interfaces for the existing DOS-based FORTRAN programs. Our students first used them in a studio environment in the Spring of 1996, and we have been making constant improvements since.

Background (Cont'd.)

- Development of Numerical Algorithms
  - » Classroom demos with graphics
- Development of User Interfaces (1995 -)
  - » UVA Teaching and Technology Initiative
- Partial Studio Model (Spring '96)

Studio Physics at RPI

Our mode of usage is somewhat like the studio mode of instruction identified most closely with RPI. At RPI Introductory Physics was taught in the usual routine of two large lectures, a recitation section and a laboratory per week; now two two-hour sessions a week in a computer classroom have replaced that earlier format. Their studio sessions include some hands-on experiments, some computational simulations, but no formal lectures. In recent years RPI has adopted the studio mode of instruction for many other courses beyond physics.

With the limited-duration support we had and the fact that many heat transfer problems involve more mathematical complexity, i.e., in general the governing equations are PDE's rather than ODEs, we were not quite ready to abandon the lecture mode entirely.

Studio Physics at RPI

- Formerly:
  - Two large lectures + recitation + lab (per week)
  - Lecture attendance: 20-30% at end of semester
- Currently
  - Two 2-hour studio sessions with no lectures
  - 60 students/section
  - Attendance > 90%
  - Faculty evaluations have soared

Partial Studio Model at UVA

For the last three years we have had two conventional lectures a week plus a two-hour studio session. In order to encourage collaborative learning, we have two students working at each PC. We have developed modules for eight of the most fundamental topics in heat transfer using a Visual Basic interface running a FORTRAN DLL. These modules were all designed and developed locally. For other weeks we have the students developing their own calculations, in most cases using a spreadsheet. For five of the modules we have a related benchtop experiment from which all students get a single set of data to compare with their computed results. We have enough students that we have to run two sections per week in the studio.

Partial Studio Model at UVA

- Two lectures/week
- One 2-hour session in studio/week
  - Special classroom with 20 PCs
  - VB/FORTRAN modules for 8 topics
  - Spreadsheet or programming for 4 other topics
  - Auxiliary table-top experiments for 5 topics
    - Specially developed by Dr. T.C. Scott
- Two sections/week for studio

Educational Software in Heat Transfer

While formulating our plans, we surveyed the available software for teaching heat transfer and decided to go ahead and develop our own. Several of the few modern packages available involved mostly the "computerization" of existing analytical solutions and experimental correlations - complete with the restrictions necessary to get the analytical solution in the first place. Most do not use modern visualization techniques to help students understand the underlying physics - something we felt we could do since we would actually be solving the underlying governing equations in real time using modern computational techniques.

Educational Software in Heat Transfer

- Limited number of available packages for instruction
- "Computerization" of analytical solutions and correlations
  - » Mainly number-crunching operations
  - » Same analytical restrictions
- Emphasis on procedure and technique
- Graphical display
  - » Limited gain in physical insight

UVA Heat Transfer Modules

To date we have developed eight modules covering nearly all the major areas of heat transfer. In some cases one could use the appropriate module to study nearly every fundamental principle discussed in the corresponding chapter in typical textbooks - both graduate and undergraduate. Several are such that a motivated user could "discover" everything he or she would be expected to learn. Others, such as the heat exchanger modules, invite use in design studies far more exhaustive than what one could dream of using the normal chart-based, pre-computer techniques.

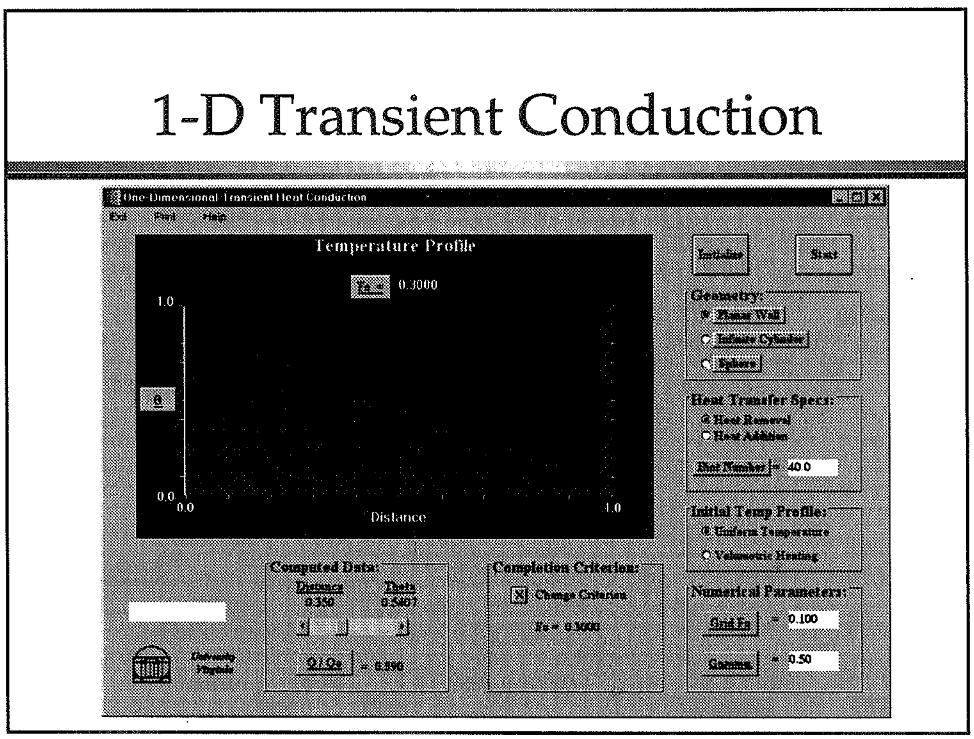
The next four slides show the user interfaces for four of the modules. The gray areas of the interface are in Visual Basic, while the graphical output seen in the black window is done directly in a FORTRAN DLL (by calling the Windows API). In all cases text boxes having a white background are for user input. Raised buttons are "hot"; i.e., when the button is clicked, a short definition of that parameter is given.

UVA Heat Transfer Modules

- Extended Surfaces (Fins)
- 2-D Steady-State Conduction
- 1-D Transient Conduction
- Forced Convection Over Flat Plate
- Internal Flows
- 1-D and 2-D Heat Exchangers
- Radiation View Factors
- Natural Convection (coming)

One-Dimensional Transient Conduction

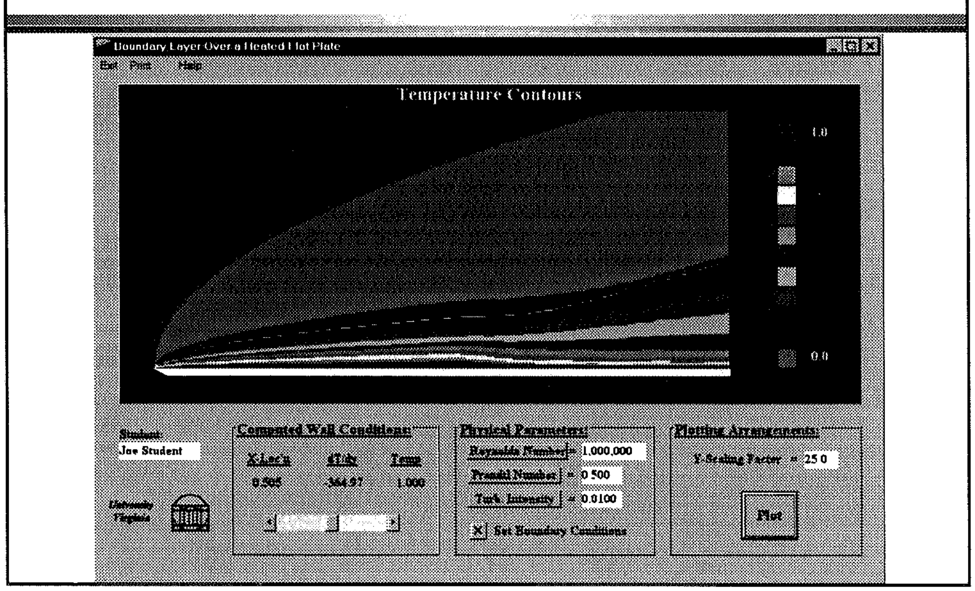
Our one-dimensional, transient conduction module does everything that the Heisler charts have been used for doing for the past half century, but unlike the latter, from which the user obtains the temperature at a single location and point in time, our module allows one to watch the entire evolution of the transient conduction process in time and space. Since it uses the finite-volume method, the same algorithm is used for the homogeneous infinite slab, infinite cylinders and the sphere, all subjected to a sudden change in the surface condition. The user can specify the surface Biot number, a stopping criterion and two numerical parameters, the timestep and the degree of implicitness. In the lower left corner the slider bar can be used to determine the numerical value of the final temperature at any point, and the total heat transferred during the process is reported. Very thorough hypertext help files covering both operation and theory are included in this module.



Forced Convection on Flat Plate

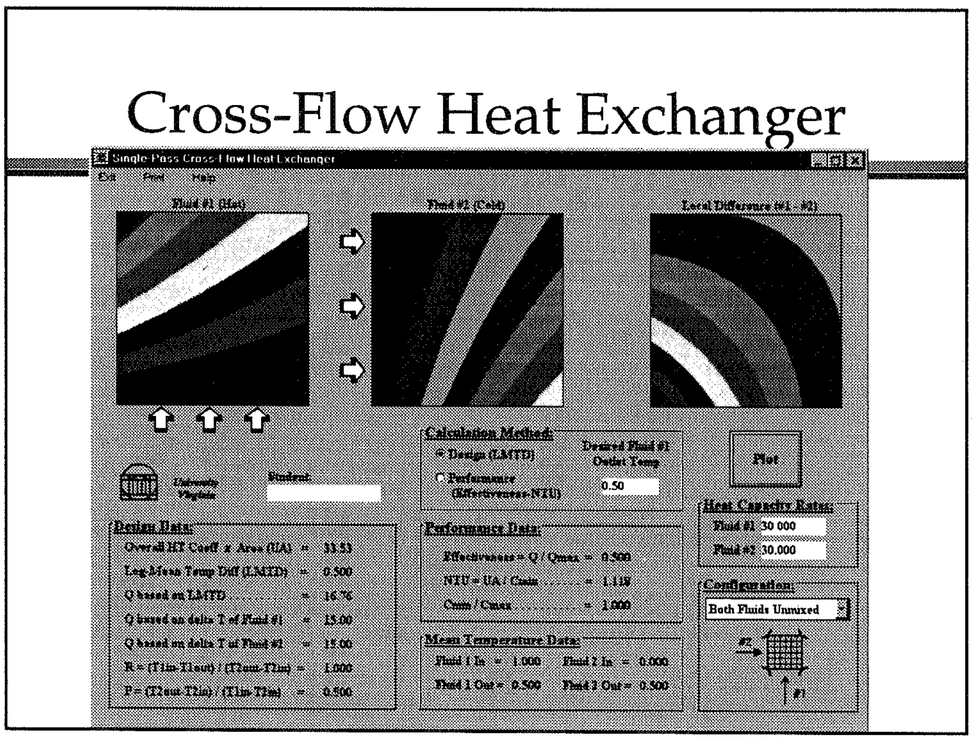
The forced convection module solves the boundary layer equations on a heated flat plate. A transition model and simple turbulence model allow it to be used across a wide range of Reynolds and Prandtl numbers. On a separate input form the user may specify a fixed temperature or specified heat flux or any combination of the two along the length of the plate. The gray region seen in the window is the extent of the computing region, which is allowed to grow along with the boundary layer. The white line shows the extent of the velocity boundary layer, while the colors are isotherms. The user can expand the vertical coordinate (in the plot below it has been expanded by a factor of 25) so that details can be seen. For the conditions used in this run, the transition to turbulence is very evident just after the midpoint of the plate. The slider bar in the lower left corner allows the user to take measurements of the surface temperature gradient and the surface temperature (depending on user specifications one is input while the other is output) as a function of position along the plate. This data may be used to develop a "virtual" correlation which compares very well with the conventional correlations.

Forced Convection on Flat Plate



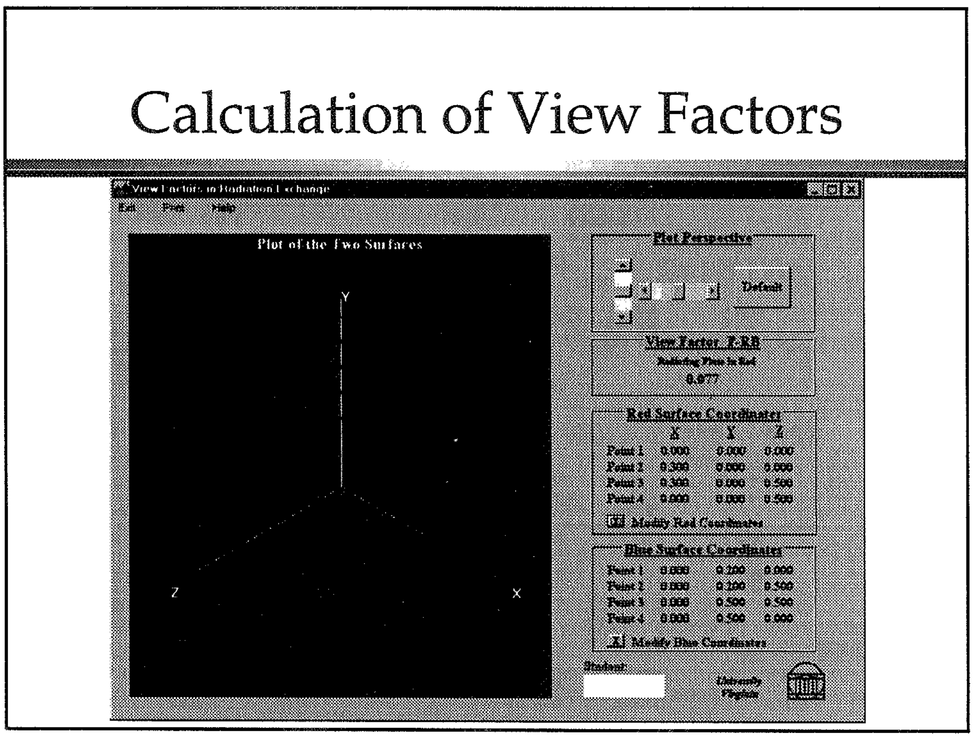
Cross-Flow Heat Exchanger

We developed two modules for heat exchanger analysis and design. This one is for single-pass, cross-flow exchangers and solves the coupled set of heat balance equations (which are PDE's). The other is for those geometries (primarily shell-and-tube) for which the governing equations are ODE's. The four possible combinations of mixed and unmixed fluids are allowed. With the complete temperature distributions available, the impact of the various operating parameters (UA, Cmin, Cmax, etc.) is readily apparent, and the user can assess the quality of the particular design. The particular case seen is for a balanced, unmixed flow condition. This case was run in the *design* mode, so the user input is the desired mean outlet temperature of the hot fluid. The contour plot on the left is for the hot fluid, the center one is for the cold fluid and the third plot shows the local difference between the two. All output data are shown in the lower half of the screen and compares nearly exactly to that found using the conventional chart-based methods.



Calculation of View Factors

This last module calculates the radiation viewfactor (fraction of radiation leaving one plate which is intercepted by a second) between two rectangles arbitrarily oriented in three-dimensional space using a computational implementation of Nusselt's Unit Sphere method. Students input the x,y and z coordinates for the two plates (on a separate input form) and then see them depicted in three-dimensional space. The slider mechanisms allow the user to view their plates from any angle, allowing a quick visual check of the data entry. The calculation takes only a fraction of a second to return the viewfactor. The implementation of the viewfactor calculation and the graphical presentation were used as two student projects in a third-year elective course in computer graphics.



Excel/Visual Basic for Applications (VBA)

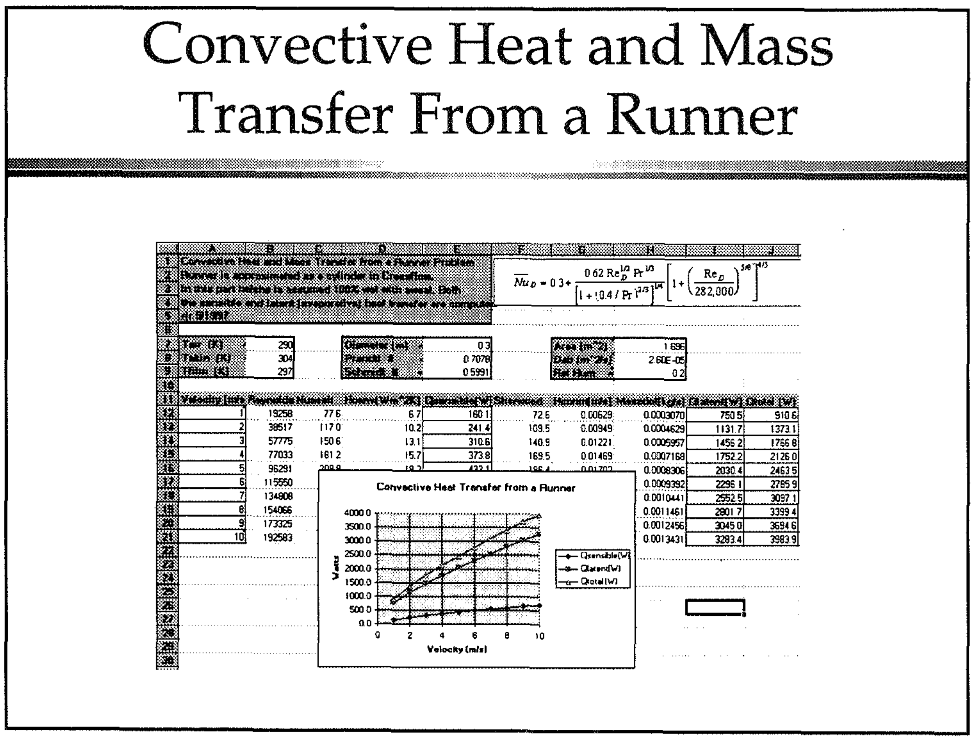
For the remainder of the sessions for which we do not have the VB/FORTRAN modules, we have developed other exercises for which we typically use Excel and Visual Basic for Applications (VBA). A spreadsheet is excellent for input and output, especially in graphical form, but generally leads to nearly-impossible-to-follow "spaghetti" code. Thus, for more complicated calculations we encourage the students to implement (using VBA) the structured programming techniques they have been taught in C++ or FORTRAN. We currently have a half dozen workbooks available on our website for downloading.

Excel/Visual Basic for Applications (VBA)

- "Light duty" calculations
- Spreadsheet for input/output including graphics (x-y plots, contour plots, etc.)
- Visual Basic for Applications for more complicated calculations
  - » Avoids tendency toward spaghetti code in spreadsheets
- Six workbooks on website

Convective Heat and Mass Transfer From a Runner

This project, in which we estimate the sensible and latent heat from a runner approximated as a cylinder in crossflow, is typical of what we do using a spreadsheet. Since nearly a dozen properties for air and water are needed for this calculation, we set up Visual Basic functions to return the values as a function of temperature. These functions are invoked from cell formulae just like the normal supplied functions like the sine and cosine. We also encourage the naming of cells so that the resulting cell formulae are easy to read and follow. Students would typically write their own VBA functions for the needed (and very complicated) forced convection correlation.



Criteria for Module Selection

Since the development of one of these modules takes a good deal of work, we selected the topics carefully. All were based on pre-existing FORTRAN programs which had been developed and improved upon, in some cases, for a dozen years. We looked for topics where modern numerical and, particularly, visualization techniques, could be used to enhance student learning and understanding of the underlying physics. All topics were so fundamental as to take at least ten pages in a typical textbook. We wanted materials that could be used in several courses; for instance, in the corresponding graduate level course where obviously more time would be spent on the modeling aspects. Finally, we chose to use no proprietary software so that these materials could be distributed freely.

Criteria for Module Selection

- FORTRAN programs already developed
  - » Improvements made over a 12 year period
- Can use modern numerical and visualization methods
  - » Enhance, not detract from, student learning
- Topic takes at least 10 pages in typical textbook
- Useable in several courses
- No use of proprietary software

Partial Studio Results

We have been pleased with the results of our experiment so far. The studio is an active, controlled collaborative environment. Students are constantly helping their peers, both with the subject matter as well as with the more mundane chores such as using the graphics capabilities of a spreadsheet. In many cases we are still using the single-correct-answer, end-of-chapter problems from the text, although with time we hope to develop more exercises that, in particular, use the visualization capabilities to develop more physical insight. We also want to stimulate the students themselves to ask more "what-if" questions as one would in the design process. Attendance in studio session has been excellent, and student response has been highly supportive.

Partial Studio Results

- Active, controlled collaborative environment
- Included text and hand calculators
  - » Used problems from text in some cases
- Usually 100% attendance in studio session and on time, too.
- President of Tau Beta Pi:
  - » "We ought to have a studio session like this in every course!"

Future Improvements

There is still plenty to do. We have not yet implemented any formal assessment of our approach. We would like to use at least some automated testing of the students - both in the form of a pre-studio quiz to ensure that they have done the necessary preparation and a post-studio assessment to see if they have mastered the material. We would like to develop a few additional experiments. We need to figure out how to motivate students to run additional cases on their own - most undergraduates are too satisfied with the typical end-of-chapter problems where they calculate a single answer and move on without forming any conclusions. Several, such as the extended surface and heat exchanger modules, invite extensive use in design, but typical texts spend most of such chapters on manual analysis methods rather than presenting good design measures.

Future Improvements

- Assessment of the method
- Automated means of testing students
- Automation of several desktop experiments
- Several new experiments
- Apply to discovery mode
- Apply to design - time left over
- Expand "Help" topics in software.

Current Status of Modules

All eight of our modules are ready for use, although several early ones do not necessarily include all the good interface design principles that we learned along the way. By May 1998 we will have used each of them three times in the studio mode. Only the two-dimensional, steady-state conduction and the one-dimensional transient conductions currently have full hypertext help files. We continue to add new features and improvements and to correct the remaining bugs constantly. Most recently we have completed a 100+ page student manual which includes for each module at least a discussion of the modeling as well as operating instructions. We are continuing to develop exercises which will more fully exploit their capabilities.

Current Status of Modules

- Eight VB/FORTRAN modules are ready for use
- All are student-tested and updated
- Help topics are incomplete for all but two
- New features/improvements/corrections being added to nearly all
- Student manual in draft form
  - 100+ pages
  - Write-up of Modeling + Operating Instructions

Lessons Learned

Prior to beginning this work we audited two instructional technology courses in UVA's Curry School of Education, so we knew already that "computerizing" topics already covered well on paper is not a good strategy. That is why we avoided "electronic page turning" and why most of these modules turned out more as "experiments" with lessons built around them. We learned that interface design is a science in itself and that pedagogical issues were just as important as the science. Perhaps just as importantly, we learned that the use of computers for instruction generates very strong feelings among one's faculty colleagues.

Lessons Learned

- There is no point in "computerizing" topics that are already well covered in text.
- Software that is "user-friendly" for industry is probably not appropriate for instruction.
- Interface design and pedagogy is just as important as the science.
- Use of computers in instruction generates strong feelings.

Some Conclusions

Finally, in this project we have made use of modern computational, visualization and interface design techniques to teach a very fundamental course. In many ways a heat transfer course is an ideal venue for this project because the traditional approach has, for many of the major topics, led inevitably to "cookbook" procedures based on the use of charts and graphs. In addition, the studio session addresses the need for computer "skills" beyond what can be covered in a first-year Introduction to Computers course. Finally, students are introduced to modern uses of information technology and computing in the form of simulations and visualization techniques.

More complete descriptions of each of the modules and some materials that are ready for distribution may be found at the presenter's website:

http://albert.ccae.virginia.edu/~rjr/modules

Some Conclusions

- Modern computational/visualization/interface techniques applied to fundamental problems.
- Alternative to "cookbook" approach to certain topics.
- Addresses need for computer "skills" beyond first year computers course.
- Challenges/interests good students who might otherwise transfer out of ME

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The Challenges of Building Educational Software That "Works"

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The Challenges of Building Educational Software that "Works"

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The Challenges of Building Educational Software that "Works"

Ralph E. Flori
University of Missouri-Rolla

Hampton, Virginia February 25, 1998

Background on the "BEST" Series

The use of the BEST acronym is not intended to be hyperbole, instead it conveys who we are and what we are attempting to do. In the Basic Engineering Department at the University of Missouri-Rolla, we are creating educational software. Originally the intent was to improve teaching, but we soon realized that the better goal was to improve learning. Improving learning has remained our goal; "BEST" remained because "BESL" doesn't have much meaning....

Background on the "BEST" Series

- "Basic Engineering Software for Teaching"
- UM-Rolla Basic Engineering Department
- BEST products under development: Dynamics, Statics, Circuits, TQM, others?
- Authored with Asymetrix ToolBook
- PC Only, not Macintosh. Run on WWW with Neuron Plugin.

About "BEST" Dynamics

The main focus of this presentation is my experiences developing the BEST Dynamics product. Under development since 1992, it has been funded by UMR, the Basic Engineering Department, the University of Missouri Institute for Instructional Development (IID), and the National Science Foundation. Contributors to the project included, at various times, five faculty members, a software engineer, and many (primarily undergraduate) students. Version 1.0 of BEST Dynamics was licensed by John Wiley in 1996 to distribute with the Riley-Sturges Engineering Dynamics text.

About "BEST" Dynamics

- Under development since 1992.

Funding from:

- UMR, and Basic Engineering Dept.
- Univ. of MO Inst. for Instructional Dev.
- National Science Foundation
- Staff: 5 faculty, Soft. Engr., many students
- Version 1.0 licensed by J. Wiley in 1996 to distribute with Riley-Sturges text.

About "BEST" Dynamics (Cont'd.)

There are two versions of BEST Dynamics. Version 1.0 was the one licensed by John Wiley. At this point in the presentation I showed examples from the software. Sample screen captures of the software may be viewed at www.umr.edu/~bestdyn.

About "BEST" Dynamics (Cont'd)

Version 1.0 Examples:

- Rectilinear Motion
- Polar Coordinates
- Four Bar Mechanism
- Planetary Gear

About "BEST" Dynamics (Cont'd.)

BEST Dynamics Version 1.0 was originally intended to be a supplement to a class. The teacher demonstrated it in class, and students used it outside of class. A typical homework assignment required the student to create his/her own set of numbers for a particular problem, run the simulation to see the animation, and for a particular instance, verify the computer's output numbers with his/her own hand calculations.

Used in this way, BEST Dynamics was found to be effective. Data show it helps improve student learning of rigid-body kinematics, as measured by their performance on quizzes and exams, compared to students who did not use the software. Students enjoyed using it and commented on evaluations that they would have liked to have used it more in the class. However, students generally do not use it unless they are required to (no surprise here).

About "BEST" Dynamics (Cont'd)

- Original concept: Supplement to class. Teacher in class, student use outside class.

Is it an effective learning tool?

- Effective as a supplement.
- Data show it helps improve student learning of rigid body kinematics.
- Students respond favorably to its use.
- (They generally do not use it unless req'd)

Limitations of BEST Dynamics 1.0

If BEST Dynamics improves learning, why doesn't everyone use it? The short answer is that as long as it remains a *supplement* to the class, it is an "add-on," used in addition to everything else. If a class is taught in the traditional way, teachers and students do all of the usual things, plus BEST Dynamics. The fact is, teachers and students have little extra time.

So what is the answer? How can we develop software that will actually be used? The conclusion I have reached is that we need educational products that are comprehensive enough that they *replace* some of what teachers and students do.

Limitations of BEST Dynamics 1.0

- As a supplement to the class, it is an "add on," used in addition to everything else.
- Teachers and students have little extra time
- If class is taught in traditional way, teachers and students do all of the usual things, plus BEST Dynamics. More work, time.
- Key: Need a product that is comprehensive enough that it *replaces* some of what we do.

Facets of Any Learning Environment

Before continuing this train of thought, I would like to diverge at this point and share why (I think) a product such as BEST Dynamics Version 1.0 cannot stand alone. According to Harvard's David Perkins, any learning environment should have the following facets. Generally, all facets should be present, though the proportions will vary.

- ◆ Information Banks (text, WWW, teacher)
- ◆ Symbol Pads (paper/pen, wordprocessors)
- ◆ Phenomenaria (models of the world that can be studied such as aquariums, terrariums, BEST Dynamics)
- ◆ Construction Kits (very open-ended, hands-on activities and/or laboratories, kits that can be assembled; a software example is Working Model)
- ◆ Task Manager (teacher, pupil, mix of both)

Conclusion: BEST Dynamics is only one facet of a total learning environment.

Facets of Any Learning Environment

According to Harvard's David Perkins:

- ◆ Information Banks (text, WWW, teacher)
- ◆ Symbol Pads (paper/pen, wordprocessors)
- ◆ Phenomenaria (e.g. BEST Dynamics)
- ◆ Construction Kits (e.g. Working Model)
- ◆ Task Manager (teacher, pupil, mix of both)

Conclusion: BEST Dynamics is only one facet of a total learning environment.

BEST Dynamics Version 2 Plans

Noting the limitations of BEST Dynamics Version 1, we began to make plans for a new BEST Dynamics, Version 2.

From a user's perspective, in Version 1.0, multiple layers of menus in the Navigation structure made it difficult to locate particular topics/problems. The theory that was there was very basic and was not situated closely with the simulation(s) that illustrated the theory. No quiz capability was present to ensure students learned what they were supposed to learn.

BEST Dynamics Version 2 Plans:

User Issues in Version 1.0 :

- Navigation layers; user can't find topic.
- Theory separate from problem simulations.
- Minimal theory.
- No quiz capability.
- Nothing to ensure they learn the intended lessons. When using a simulation, if they don't know to ask the question, won't learn.

BEST Dynamics Version 2 Plans

From a programmer's perspective, BEST Dynamics Version 1.0 was not very modular. It was difficult to add new problems, theory and other elements into the existing menu structure. The simulations ran too fast on fast processors, and a user could step simulations backwards in time.

BEST Dynamics Version 2 Plans:

Programming perspectives on Version 1.0 :

- Not very modular
- Difficult to add new problems, theory
- Simulations run too fast on fast processors
- Cannot step simulations backwards in time

BEST Dynamics Version 2

BEST Dynamics Version 2 is being implemented. Its key features include:

- **Modularity:** Various educational elements such as theory, simulations, quizzes, help, media (audio/video/pictures), etc., are "classes" with defined properties. These elements exist as separate classes, and any page can have one or more of these classes "plugged into it." The value of this is that the developer can juxtapose various educational elements on the same page. For example, quiz questions can be served next to a theory section or next to a simulation.
- **Navigation that reveals program structure:** Version 2 has a tree structure navigational system with main headings that expand to show subheadings. The modules that comprise the program can be added or deleted from the navigation structure very easily (simply by editing a text file read at startup by the navigator) if a user wishes to customize his/her implementation of the product.
- **Simulations on time basis from PC clock**
- **Scaleable simulations can be embedded in theory.** The simulations illustrate theory, and the theory illuminates the lessons in the simulations.

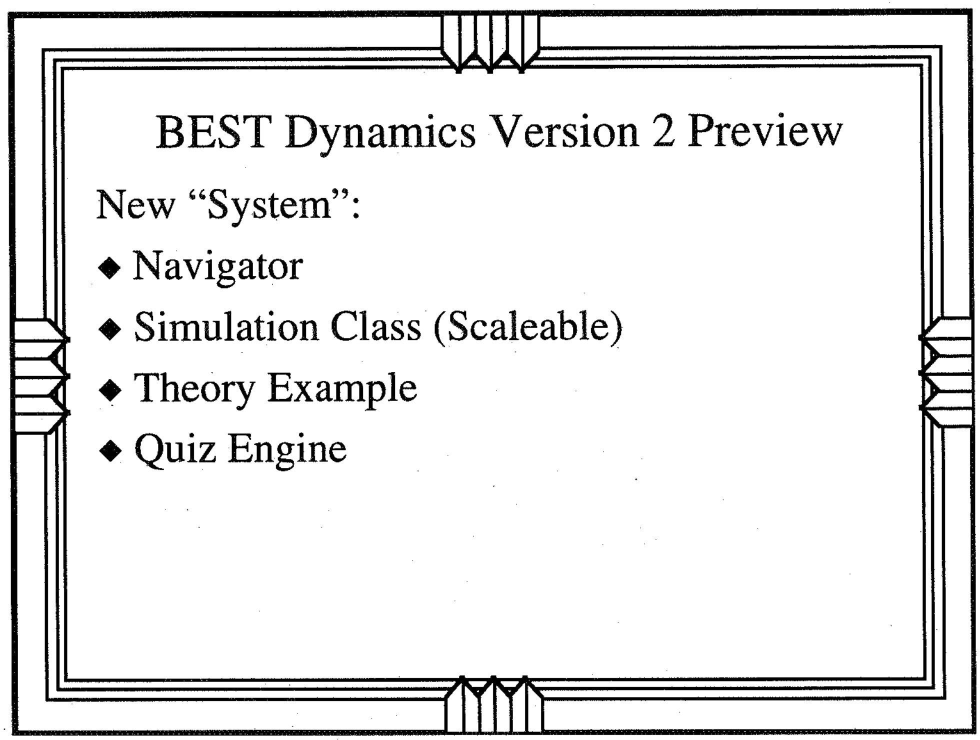
BEST Dynamics Version 2

Our Plan:

- Modularity: Various classes with defined properties: theory, simulations, quizzes.
- Navigation that reveals program structure
- Simulations on time basis from PC clock
- Scaleable simulations can be embedded in theory. Simulations illustrate theory; theory illuminates lessons in simulations.

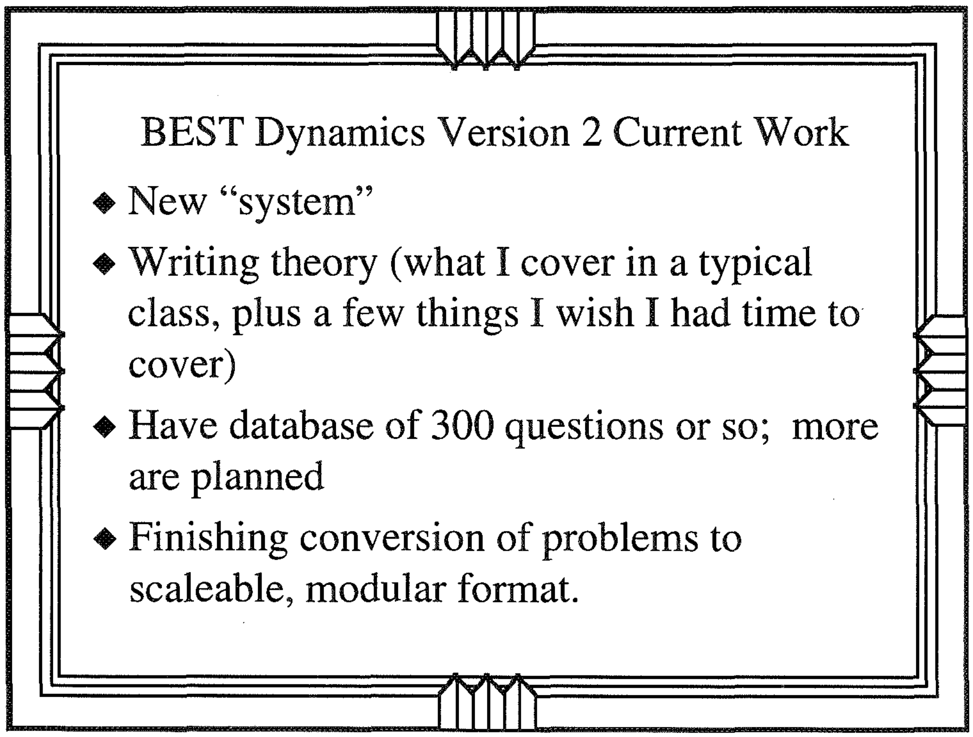
BEST Dynamics Version 2 Preview

At this point in the presentation I showed examples of the new system, including the Navigator, a simulation, a theory example, and the quiz engine. Screen captures are not available at this time.



BEST Dynamics Version 2 Current Work

- New "system" (described in previous slides)
- Writing theory (what I cover in a typical class, plus a few things I wish I had time to cover)
- We have a database of 300 questions or so; more are planned
- Finishing conversion of problems to a scaleable, modular format.



Philosophical Issues

(Things I think I know about educational software)

- It must benefit both **teachers** and **students**.

In order to benefit the **student**, it must:

- Be easy, fun, interesting, and engaging to use.
- Offer direct, clear paths to understanding key ideas (that they must know and will be tested on).
- Assess, via quizzes or other interaction, student grasp of information, and give feedback.
- Be an integral part of the course.

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Philosophical Issues (Cont'd.)

In order to benefit the **teacher**, it should:

- Make teacher's job easier. Shift more of the responsibility for learning from teacher to student.
- Teach remedial, elementary, and mid-level concepts in the course at least as well or better than a master teacher.

Years ago: Students carried more responsibility (it seems to me).

Today: Teachers often carry more than students. (I often put homework solutions in the library for the mechanics classes I teach. I put a lot of time into the solutions, with careful drawings and extra explanatory notes. Occasionally, I pick up homework for which the solutions are available. Invariably, the students put much less time into their work than I did. They omit important pictures. When I see this I admonish them somewhat along these lines:"Something is wrong here! I spend a lot of time doing this work very carefully, but I already know how to do it! You, who don't know and should be learning how, approach it in a very shallow manner! You are the ones, not me, who should take extra time to draw pictures and to reinforce understanding.)

Philosophical Issues (Cont'd)

In order to benefit the teacher, it should:

- Make teacher's job easier. Shift more of the responsibility for learning from teacher to student.
  Years ago: Students carried more responsibility.
  Today: Teachers often carry more than students.
  (Example of my library homework...)
- Teach remedial, elementary, and mid-level concepts in the course at least as well or better than a master teacher.

Philosophical Issues (Cont'd.)

In order to benefit the **teacher**, it should:

- Periodically assess student learning of key ideas so teacher grades less homework and quizzes.
- Better utilizes the teacher, freeing him/her to interact with students with higher-order concepts, examples.
- Be an integral part of the course, replacing some (much) of what we normally do in class.
- Enable a three-hour class to meet less than three times per week, because of increased out-of-class student effort.

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Ideal for Mechanics Courses

- These kinds of software products would be ideal for foundational engineering courses because of the highly structured nature of the material.
- Must have teacher involvement and student-student collaboration to help develop higher-order thinking skills.
- Comprehensive software such as this would help give students conceptual foundations that would complement/undergird collaborative learning.
- Teachers are inevitably faced with trade-offs. Time limitations in class force teachers to focus and be selective regarding their coverage. It is usually impossible to cover everything from basics to advanced topics. If a teacher focuses on advanced topics, many students are lost. If a teacher focuses on introductory (actually, remedial or review) and intermediate level topics, he/she will likely never get to advanced topics. The lower tier of students may be satisfied, but the upper tier and the teacher are not. Quality software should help shore up these foundations, in an individualized way, and enable the classroom time and the teacher's time to be better utilized.

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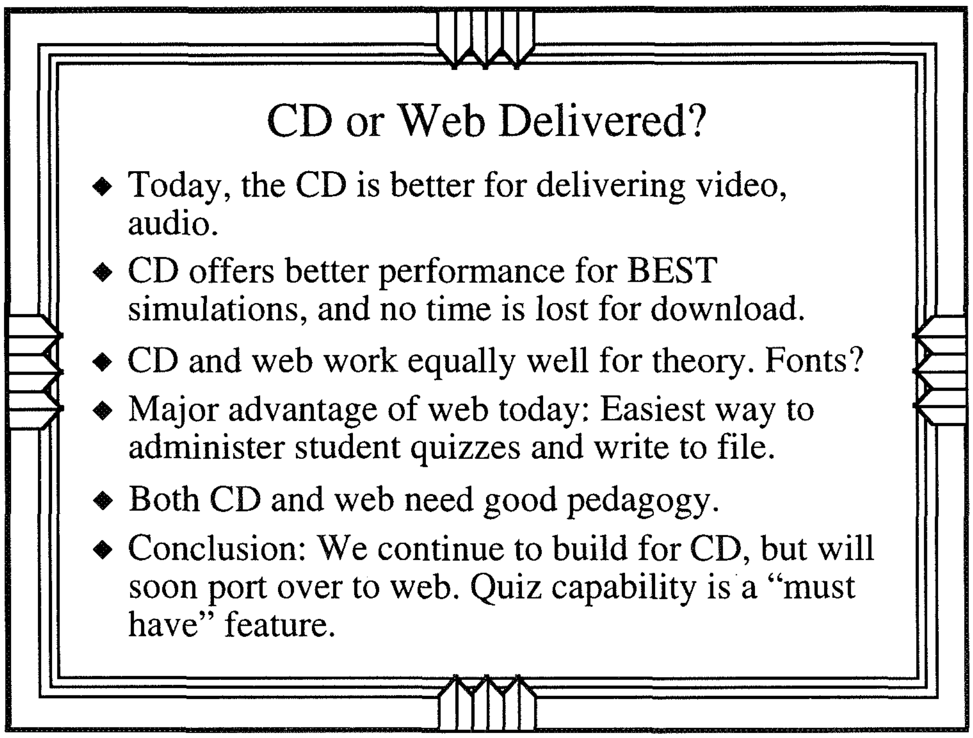
CD or Web Delivered?

- Today, the CD is better for delivering video, audio.
- CD offers better performance for BEST simulations, and no time is lost for download.
- CD and web work equally well for theory (at least the textual part of theory). But fonts and equations are troublesome.
- Major advantage of web today: Easiest way to administer student quizzes and write to file.
- Both CD and web need good pedagogy.
- Conclusion: We continue to build for CD, but will soon port over to web. Quiz capability is a "must have" feature.



Summary

- Software must be comprehensive, supporting as much of the course as possible. Not an "add on," it should replace some of what we do. Transforms, not replaces, the teacher/student relationship.
- It must have quiz (assessment) capability.
- Dilemma: Building comprehensive software that makes a difference, that covers all material in a course is like writing a book. It is extremely resource-consuming. Our universities and funding agencies must understand this.

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"I Have a Dream...."

- Of educational software that satisfies both teachers and learners. It improves how students learn and better utilizes teachers.
- Of enough money to produce such software.
- Of being able to find enough talented programmers who are dedicated to the project.
- Of having enough time myself to lead the projects and to write theory and develop problems.
- Of technology that changes fast enough to make development easier, but not to make it obsolete.

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Control Tutorials for Matlab: Software Instruction Over the World Wide Web

Dawn Tilbury
University of Michigan
Ann Arbor, MI

and

William Messner
Carnegie Mellon University
Pittsburgh, PA

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Control Tutorials for Matlab: Software Instruction Over the World-Wide Web

Dawn Tilbury
Mechanical Engineering and Applied Mechanics Department
University of Michigan
Ann Arbor, MI 48109
and
William Messner
Mechanical Engineering Department
Carnegie Mellon University
Pittsburgh, PA 15213

The Control Tutorials for Matlab were developed jointly by Dawn Tilbury at the University of Michigan and Bill Messner at Carnegie Mellon University. Funding was provided by the National Science Foundation under Grant DUE 9554819.

Project Goal, Methods and Results

The goal of this project is to teach students to use Matlab to design and analyze control systems. We wanted to allow students to quickly use the information that was presented to them, and to have the information on Matlab available when and where they needed it. In addition, we wanted to give the students many examples that they could look at. The result of this project is a set of widely-available, easily-accessible tutorials.

Project Goal:

- Teach Matlab for control system design and analysis

Methods:

- Allow student to quickly use presented information
- Information available "when and where" it is needed
- Many examples at different levels of difficulty

Result:

- Widely-available, easily-accessible tutorials

Assumptions and Tutorial Content

We assumed that the students who would use our tutorials are already taking a course in automatic control. The theoretical content of the tutorials is minimal, and the emphasis is on using the software package (Matlab) to apply that theory to practical examples. One side effect of this framework is that engineers in industry who learned the theory of classical control many years ago can use the tutorials to quickly come up to speed on using Matlab.

Assumption:

- Students are taking a course in automatic control

Tutorial Content:

- Theoretical treatment is cursory
- Emphasis is on the use of software (Matlab) to design and analyze control systems

Side Effect:

- Useful for continuing education:
  Engineers who know classical controls can learn to use Matlab

Design Objectives

The design objectives that we worked with were that the tutorials should be easily accessible to students who were working with Matlab, and they should be interactive; that is, the students should be able to run the Matlab code easily. We wanted the tutorials to be highly connected, and related information to be made available to the students in a quick and easy manner. Students like to see lots of examples, so we wanted to include as many as possible. We wanted the tutorials to be portable from one place to another (initially Michigan and Carnegie Mellon). Since the tutorial concept was so new, we wanted a means to receive user feedback.

Design Objectives

- Easy accessibility
- Interactivity ("learn by seeing and doing")
- Easy availability of related information (interconnectivity)
- Many examples
- Portability
- User feedback

Advantages of Tutorials on the WWW

From the design objectives we outlined, we decided to implement the tutorials in HTML on the WWW. This allows the tutorials to be immediately available to students anywhere, any time. Students can copy the Matlab code off the web page and paste it into Matlab to run it, allowing them to quickly get up to speed in using Matlab. In addition, HTML allows the tutorials to be very interconnected and to allow many different paths through the tutorials.

Advantages of Tutorials on the WWW

- Immediately available to any student, anywhere
- Students can learn by seeing and doing (interactivity)
- Interconnectivity: students can choose the most appropriate path through the tutorials

Portability

The tutorials are also very portable because they are implemented in HTML. Web browsers and Matlab are available on almost every platform: Mac, Windows, Sun, HP, SGI, etc. Everything is plain text, or gif files for pictures and equations. Local file references were used for all links so the complete set of tutorials can be transported from one site to another with no editing. Copies have been available to interested universities (and industries) since Jan. 1997; currently, more than 75 remote installations on six continents exist.

Portability

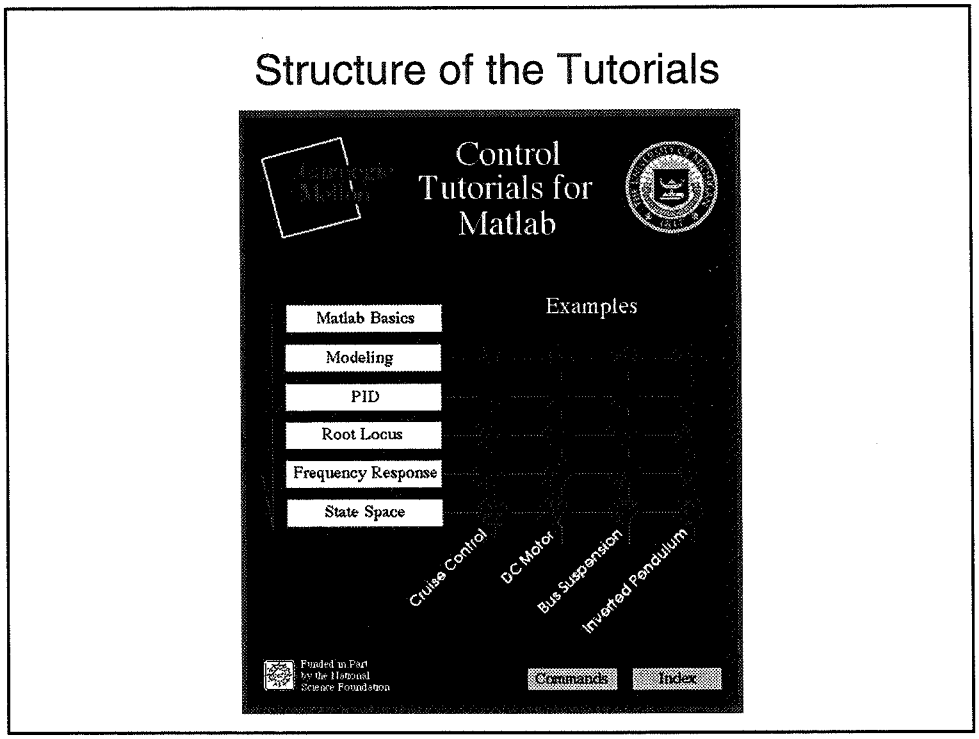
- Local file references
- Client-side image map
- Small image sizes

- Copies available by ftp
  (contact authors for instructions)

- Fifty remote installations on six continents
  (Antarctica eludes us)

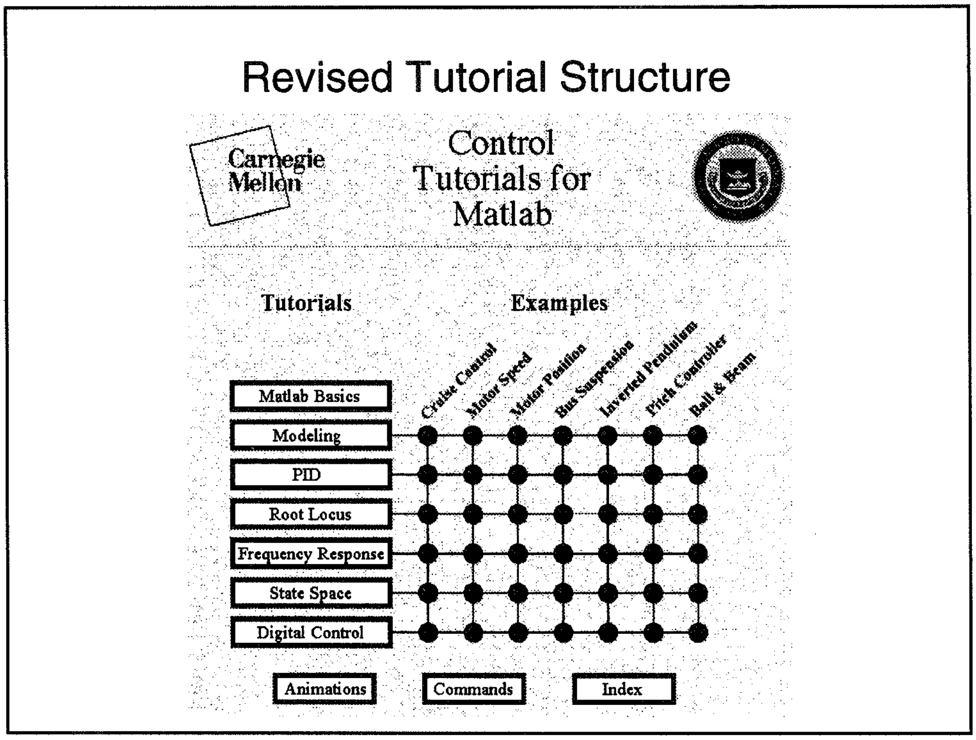
Structure of the Tutorials

The home page of the tutorials is an image map which shows the structure of the tutorials. The tutorials follow the outline of the most popular textbooks in automatic control. There are four examples which are followed through the tutorials. The structure is truly nonlinear: a student could follow only the tutorials, or start at the root locus tutorial and study all the root locus examples, or study all of the different control design techniques applied to the bus suspension example.



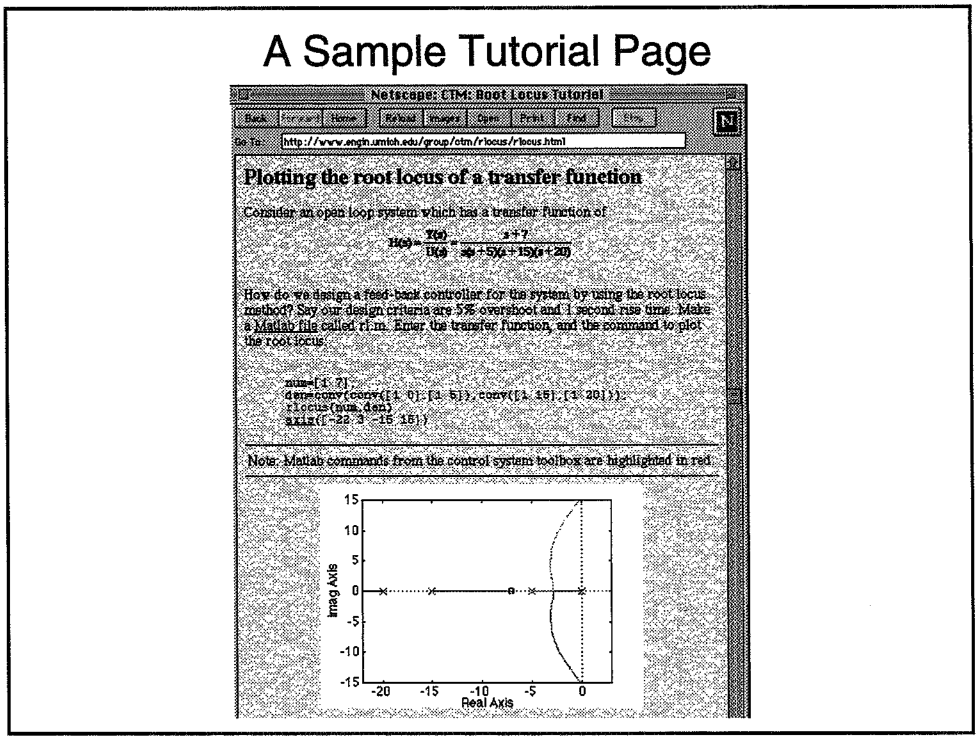
Revised Tutorial Structure

When the tutorials were revised over the summer of 1997, we added three more examples (we still get email asking for even more examples) and a tutorial on digital control (a popular request). We also added some interactive animations to help students visualize the effect of control on physical systems.



A Sample Tutorial Page

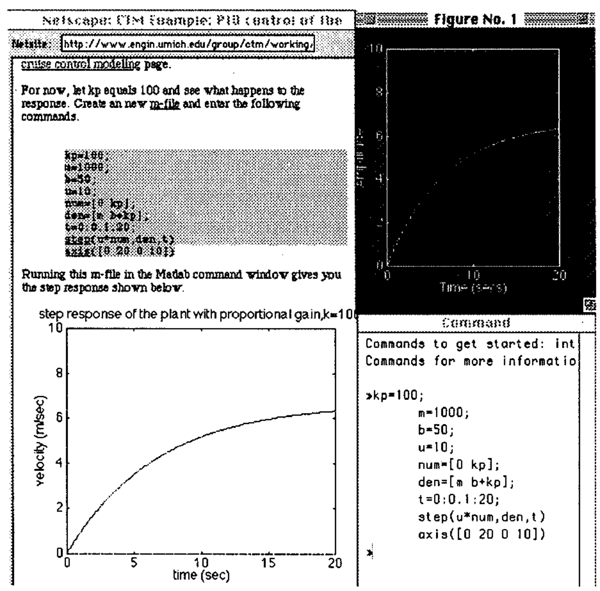
A sample tutorial page shows the combination of text, equations, pictures, and Matlab code. When the Matlab code is copied and pasted into Matlab, the root locus figure shown will result.



Usage of the Tutorials

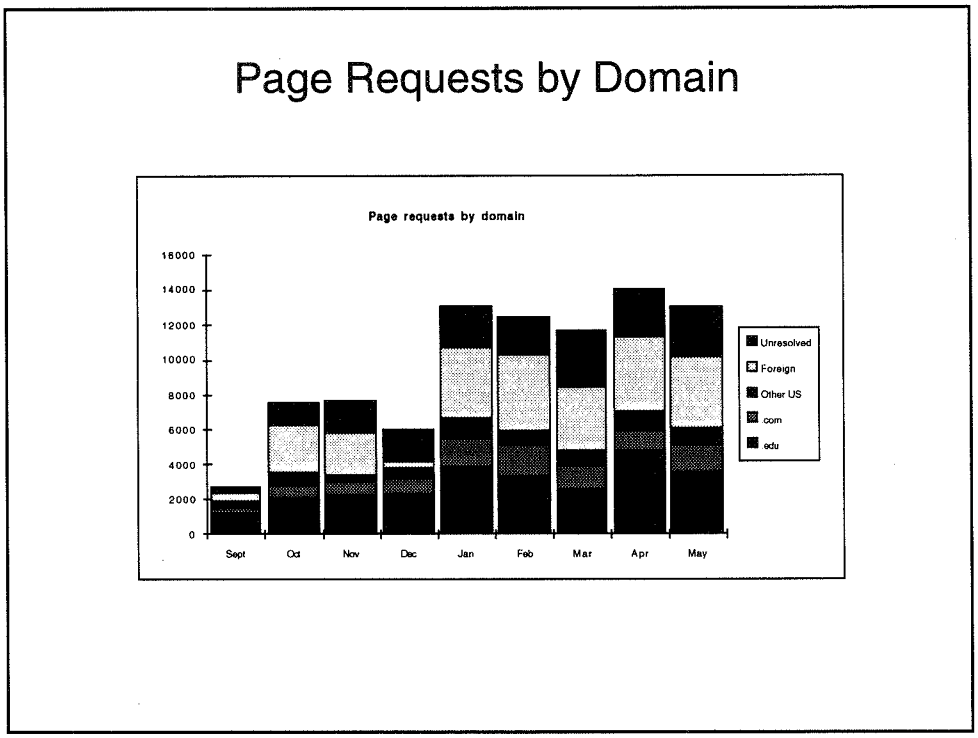
This figure shows how the tutorials are used, with Netscape in one window and Matlab in the other. When the Matlab code is copied out of the web browser window and pasted into the Matlab window, the step response plot results.

Usage of the Tutorials: Netscape and Matlab



Usage Statistics: Page Requests by Domain

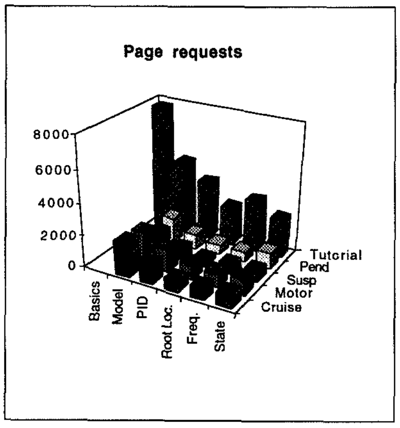
Statistics were gathered from the University of Michigan's web site. Each page is a tutorial or example page. The tutorials went on-line in Sept. 1996, and gained in popularity over the Fall term. The academic calendar is shown by the drop in access in December, March and May. February has more hits per day than January, but it is a shorter month. The tutorials were first made available to remote installations in January; publicity was through an electronic newsletter and a mailing to all department chairs of EE and ME in the US.



Usage Statistics: Page Requests by Page

Here the usage statistics by page are shown. The tutorials are much more popular than the examples, and the basics tutorial is far and away the most popular page (evidently, not everybody is as interested in controls as we are!).

Usage Statistics

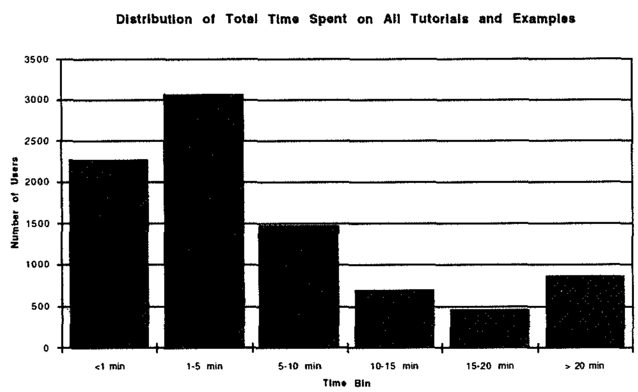


Total hits per page at UM
Sept. 96-Jan. 97

Usage Statistics: Total Time Spent

We estimated the time that users spent on the tutorials by subtracting the time of the first and last hit from a given IP address. These statistics show that the tutorials are most commonly used for a quick reference, but are sometimes used for in-depth study.

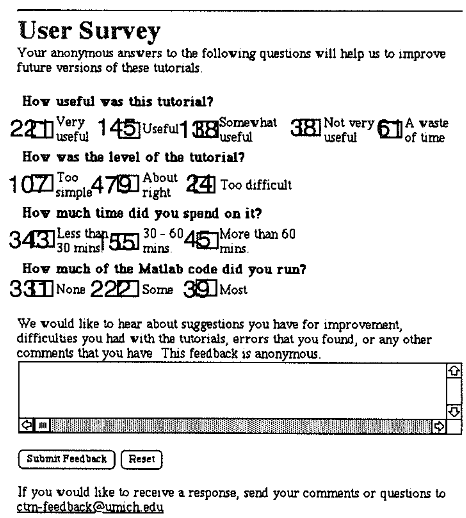
Time Spent on All Tutorials and Examples



Feedback From Users

At the bottom of every tutorial and example page, there was a feedback 'form' (in HTML) where users could click on radio buttons to tell us what they thought about the tutorials. Only a small fraction of the users filled out this information, but those who did seemed to like the tutorials overall.

Feedback From Users, Sept. 97-Jan 97



User Survey

Your anonymous answers to the following questions will help us to improve future versions of these tutorials.

How useful was this tutorial?

221 Very useful 145 Useful 138 Somewhat useful 38 Not very useful 61 A waste of time

How was the level of the tutorial?

107 Too simple 479 About right 24 Too difficult

How much time did you spend on it?

343 Less than 30 mins. 155 30 - 60 mins. 45 More than 60 mins.

How much of the Matlab code did you run?

331 None 222 Some 39 Most

We would like to hear about suggestions you have for improvement, difficulties you had with the tutorials, errors that you found, or any other comments that you have This feedback is anonymous.

Submit Feedback | Reset

If you would like to receive a response, send your comments or questions to ctm-feedback@umich.edu

Feedback Comments

Here is a sampling of the free-form comments that we got from the feedback forms. Popular requests were for digital control, more examples, and Simulink tutorials; the first two were included in the revision, the latter will be included in a published version.

Feedback Comments:

Thanks for the tutorial. I needed to learn Matlab basics for a project I was working on and I found the tutorial to be very helpful. I had no Matlab experience so I thought that the tutorial was at the right level.
(Lockheed Martin Corporation)

I am taking a class now on controls and the examples you provide on this page are as good or better than anything I have found. Also, being able to snap code off the web page and then run in Matlab is also very useful! (University of Wisconsin-Milwaukee)

I'm currently taking a controls course and I was confused on how the zeros and poles effected the root-locus - your tutorial was very helpful. Thanks... (Virginia Tech)

Very good idea to teach using WWW. I hope more people will use your concept. I think the whole course or other courses could be taught in that way. (Quebec)

Updates and Future Directions for the Tutorials

Over the summer of 1997, we updated the tutorials by adding a new tutorial on digital control and more examples. We also included some interactive animations. The tutorials will be published by Addison-Wesley in 1998 as a CD-ROM textbook supplement; we will update them to Matlab 5 and include a Simulink tutorial. We would like to see the tutorial concept extended to other applications of Matlab as well as tutorials for other software packages.

First Update, Summer 1997

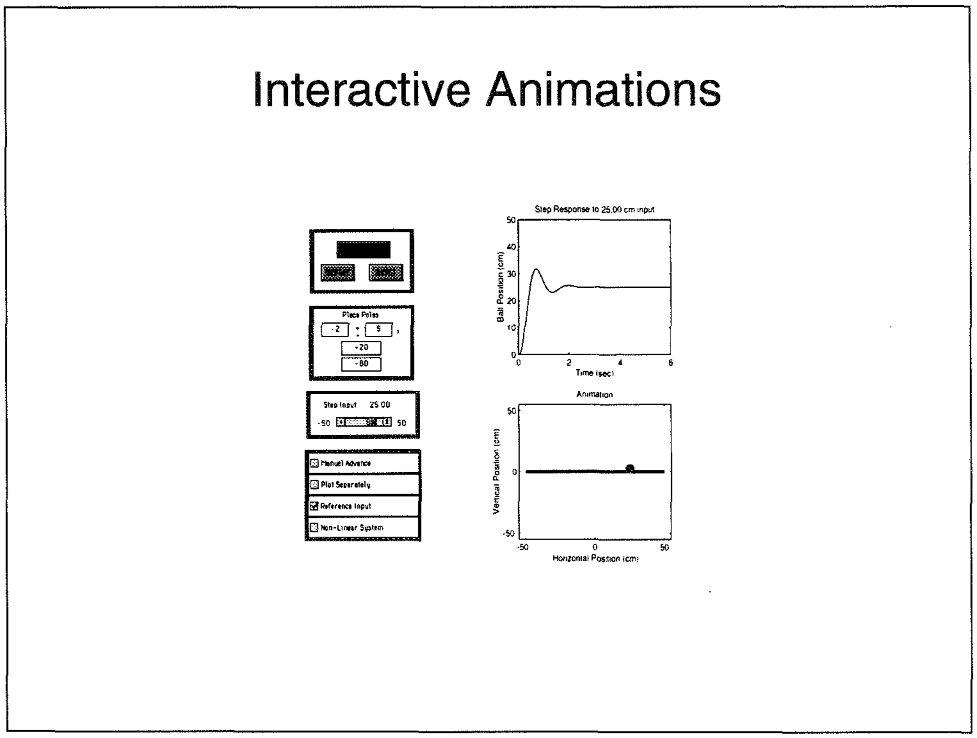
- New topics (digital control)
- More examples (ball and beam, aircraft pitch control)
- Interactive control animations

Future Directions

- CD-ROM to be published by Addison-Wesley, 1998
- Simulink tutorials
- Control laboratories (virtual and physical)
- Other software tutorials
  Mathematica, ANSYS, ProEngineer

Interactive Animations

The interactive animations were written in Matlab. Java was evaluated as a potential language, but not enough infrastructure is available (code solvers, etc.). Since the animations complement the Control Tutorials for Matlab, we felt that assuming users had access to Matlab was not unrealistic. When the animation window comes up, some default parameters are entered; the user can just click "run" to go. In this example, the beam is rotated, the ball rolls along the beam, and then the beam is returned to level to 'catch' the ball in the desired position. Users can change the desired set point for the ball, the closed-loop poles of the system, and can choose to simulate the linear or nonlinear system. Animations are also implemented for the bus suspension, pitch controller, and inverted pendulum.



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The Mississippi NASA Community College Initiative

Pamela B. Lawhead
University of Mississippi
University, MS

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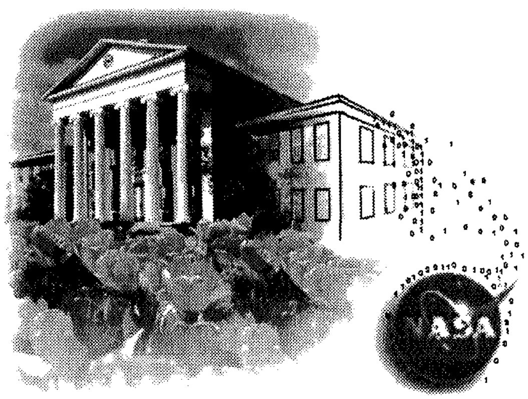
The Mississippi NASA Community College Initiative

Pamela B. Lawhead
Department of Computer and Information Science
University of Mississippi
University, MS 38677

The Mississippi NASA Community College Initiative

Pamela B. Lawhead
The University of Mississippi

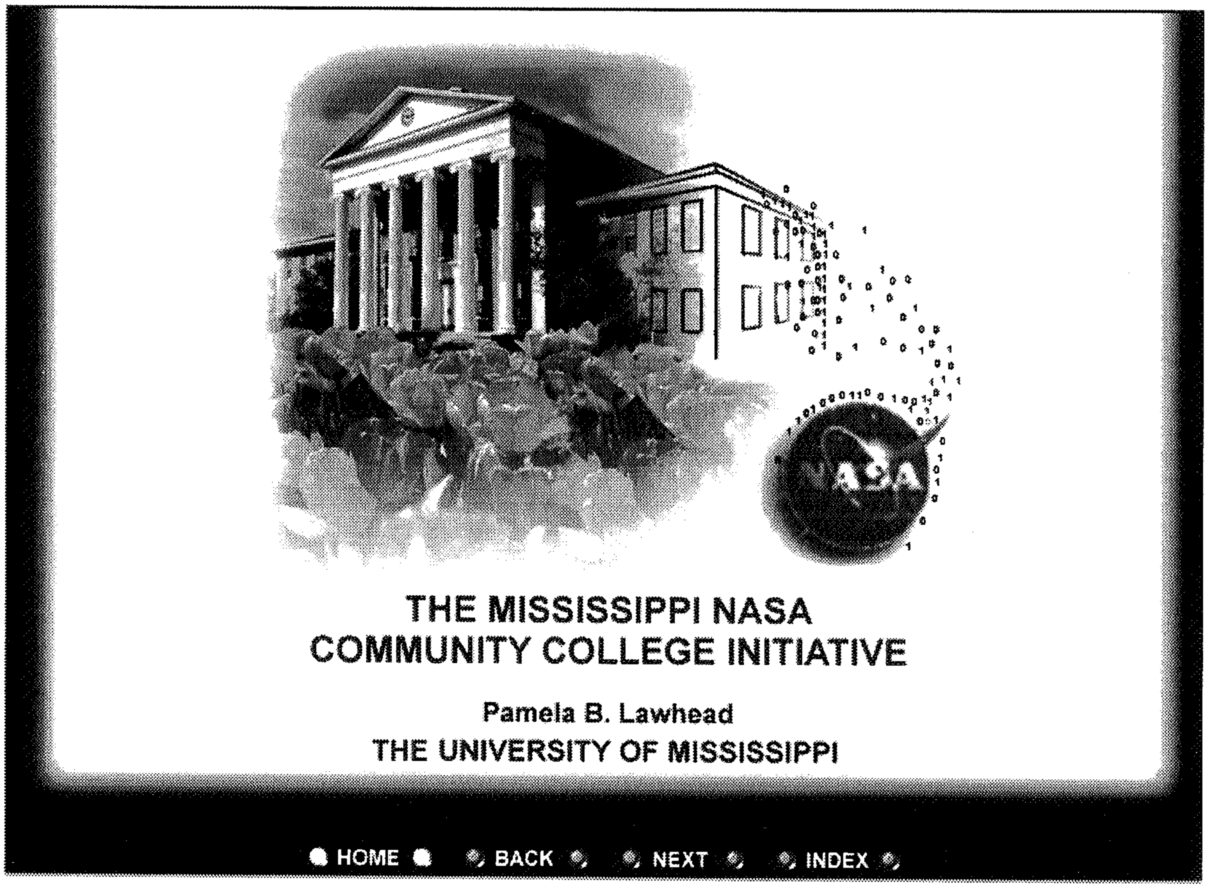


THE MISSISSIPPI NASA COMMUNITY COLLEGE INITIATIVE

Pamela B. Lawhead
THE UNIVERSITY OF MISSISSIPPI

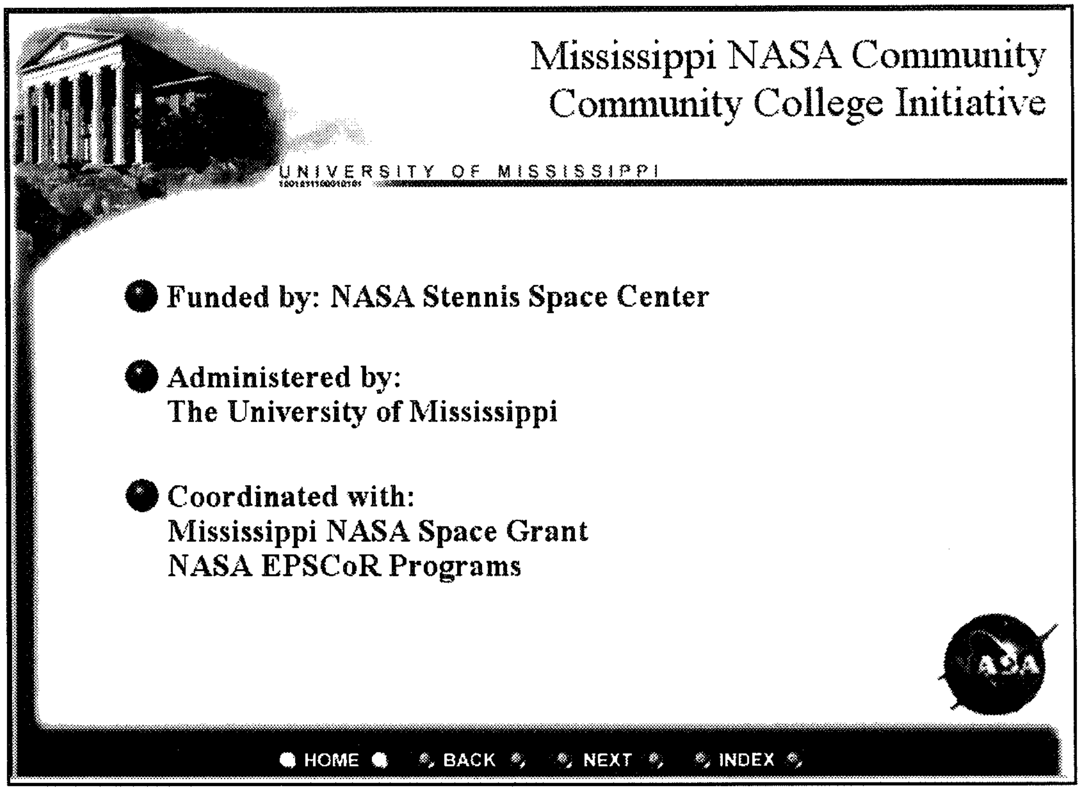
The Mississippi NASA Community College Initiative

This presentation was created using Javascript, HTML, and VRML. The slide show is being served in real-time from a Xitami web server running on this laptop.



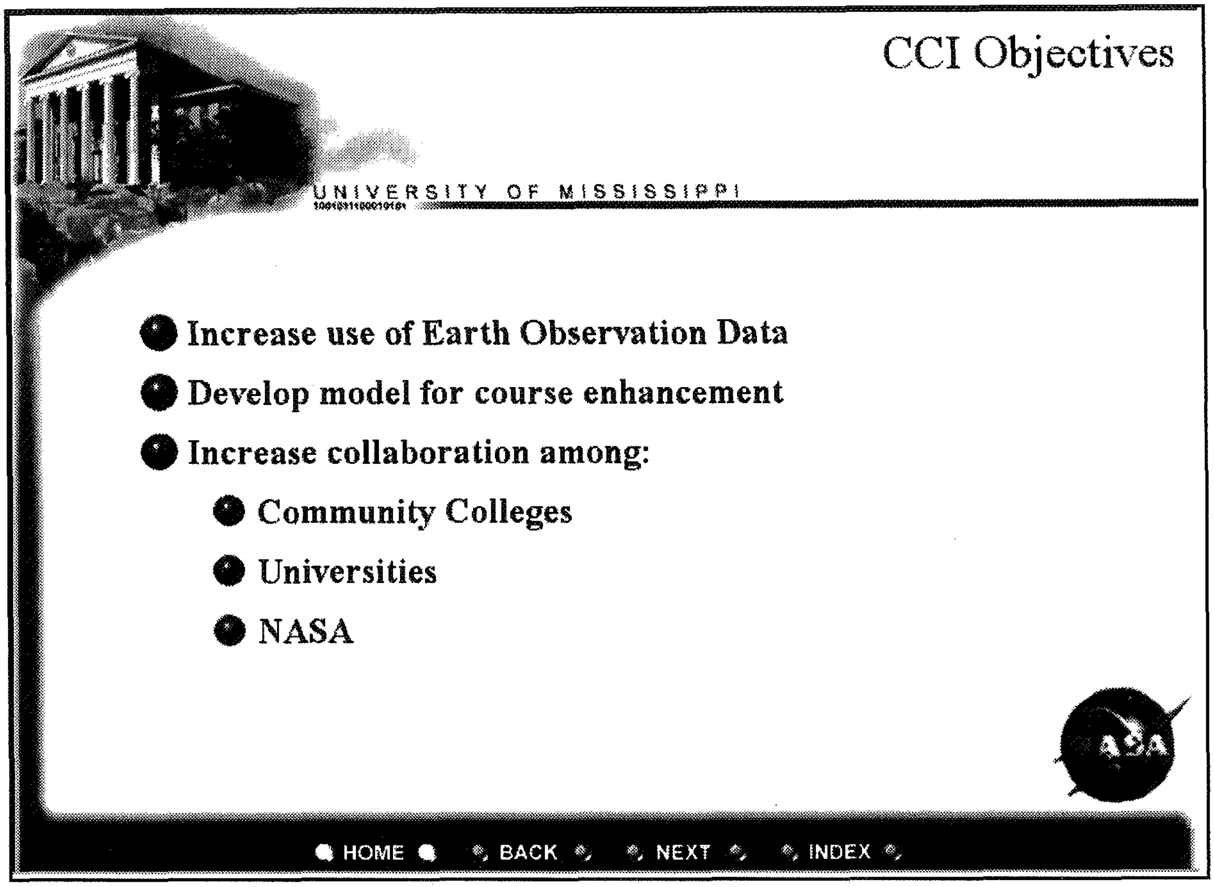
Sponsors

The sponsors of the Mississippi NASA Community College Initiative are NASA Stennis Space Center, The University of Mississippi, and the Mississippi NASA Space Grant EPSCoR Programs.



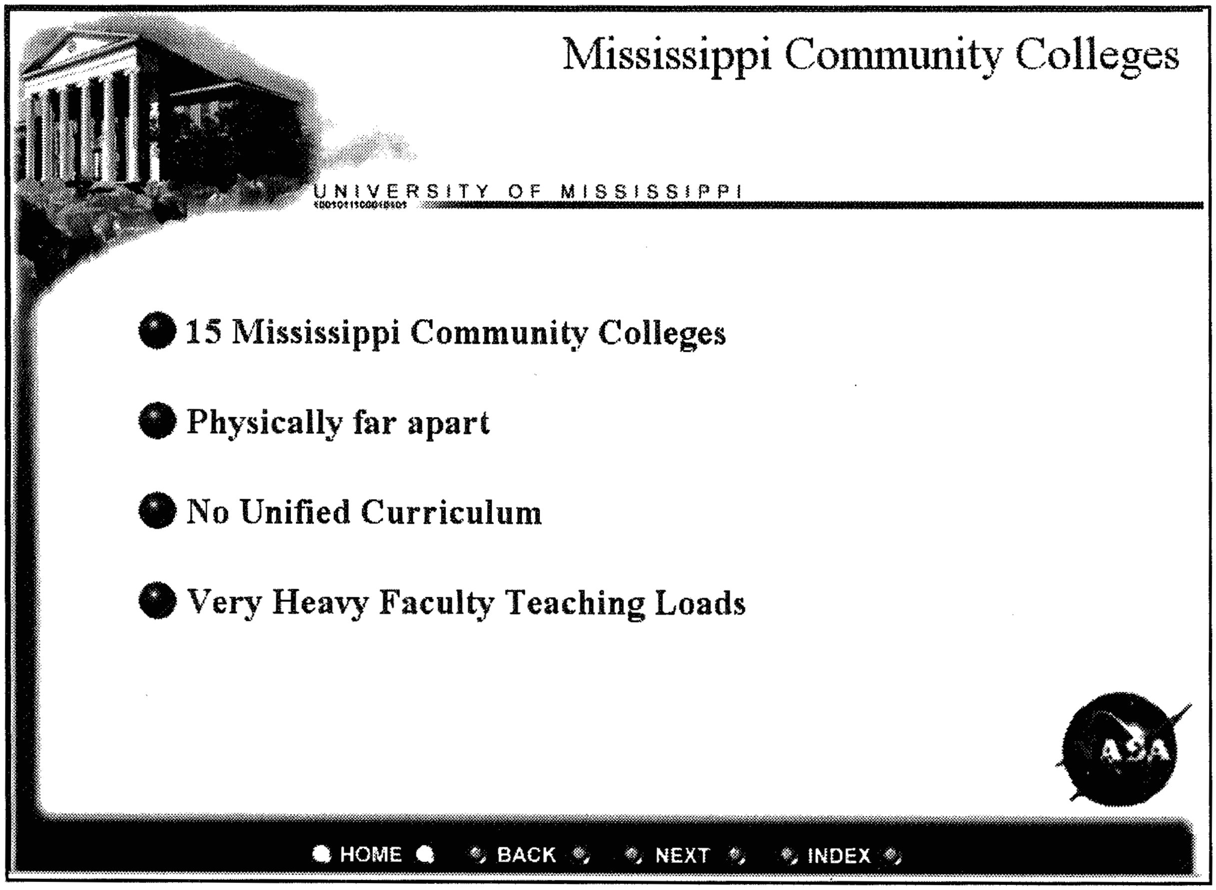
Objectives

The object of this project was to provide greater utilization of existing resources to enhance the educational opportunities of Mississippi Community College students.



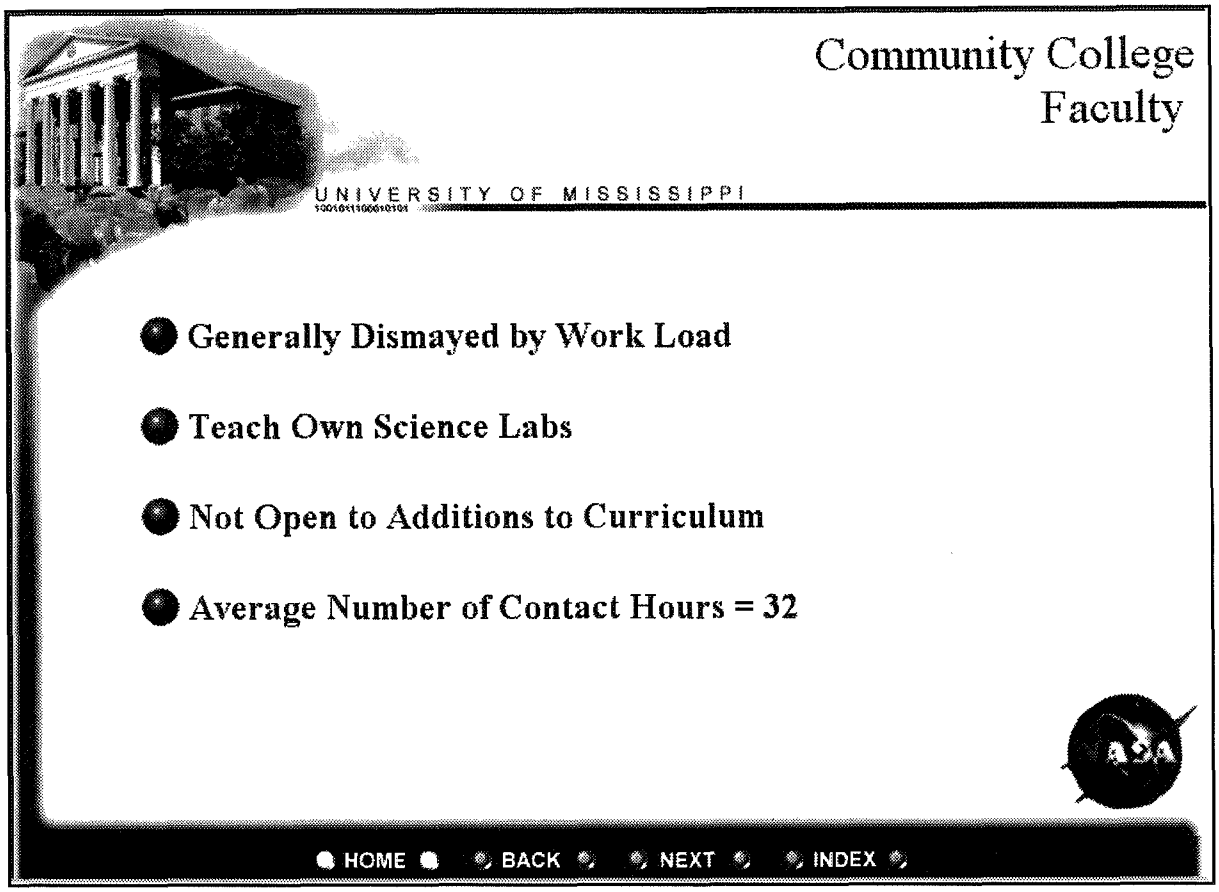
Mississippi Community College Profile

The fifteen Mississippi Community Colleges participating in the program were not utilizing shared resources for science curriculum.



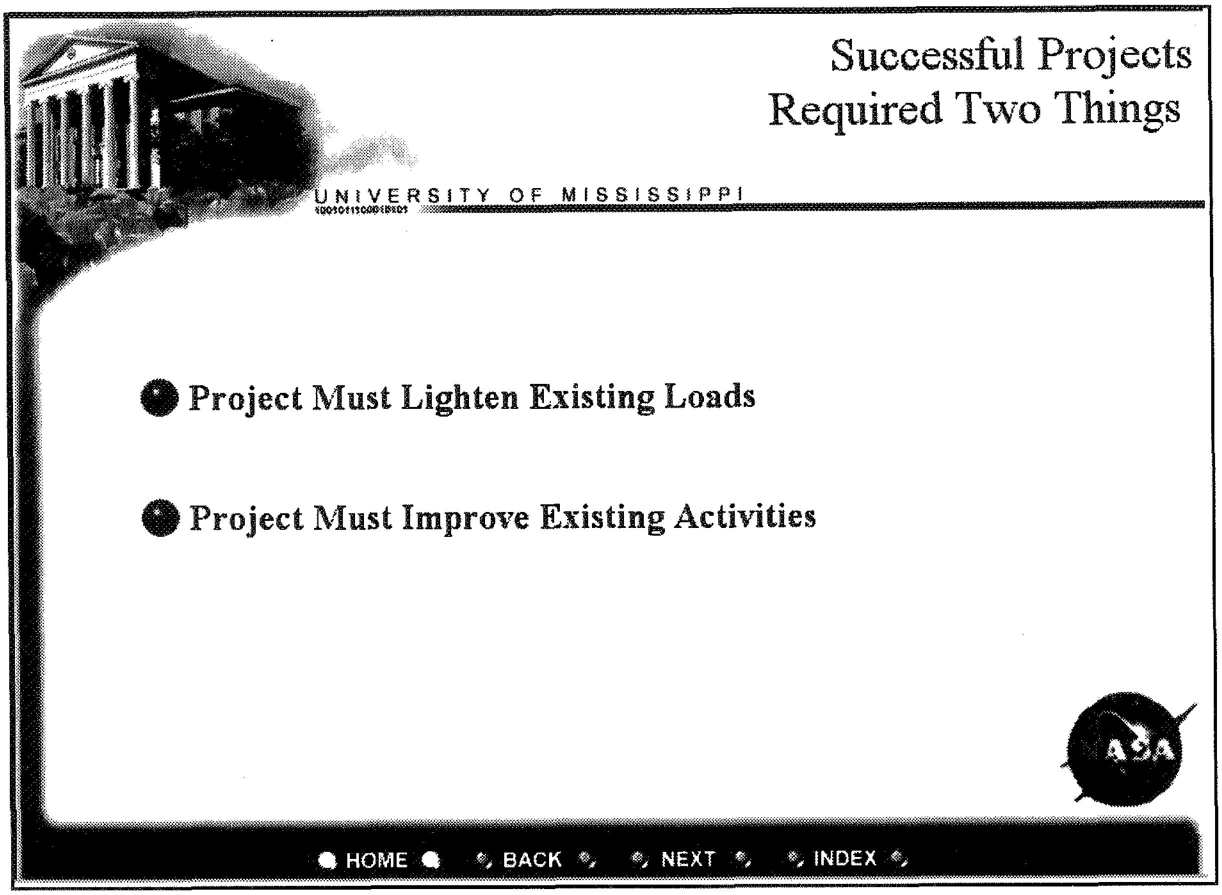
Community College Faculty

The science faculty at the Community Colleges showed some uniform qualities.



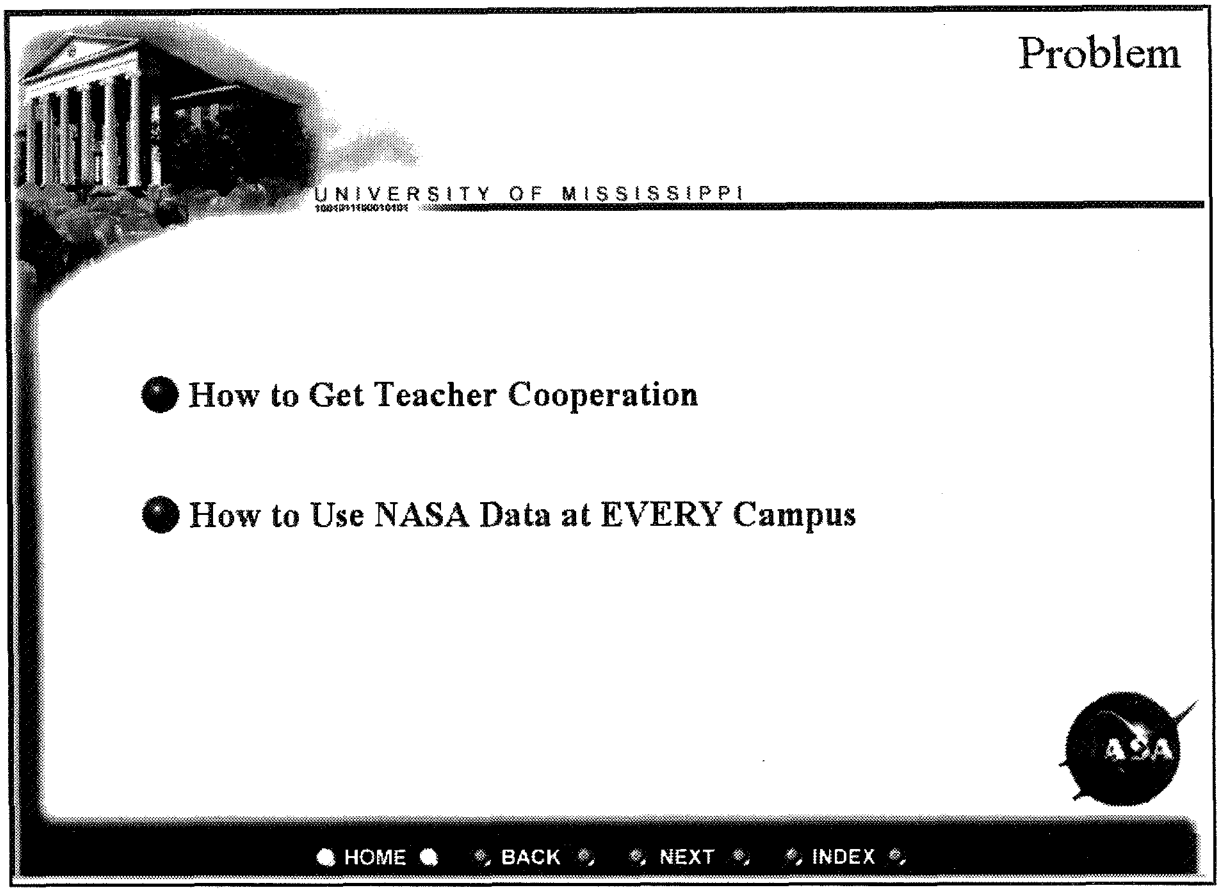
Requirements for Success

The science faculty had to agree to utilize the new resources.



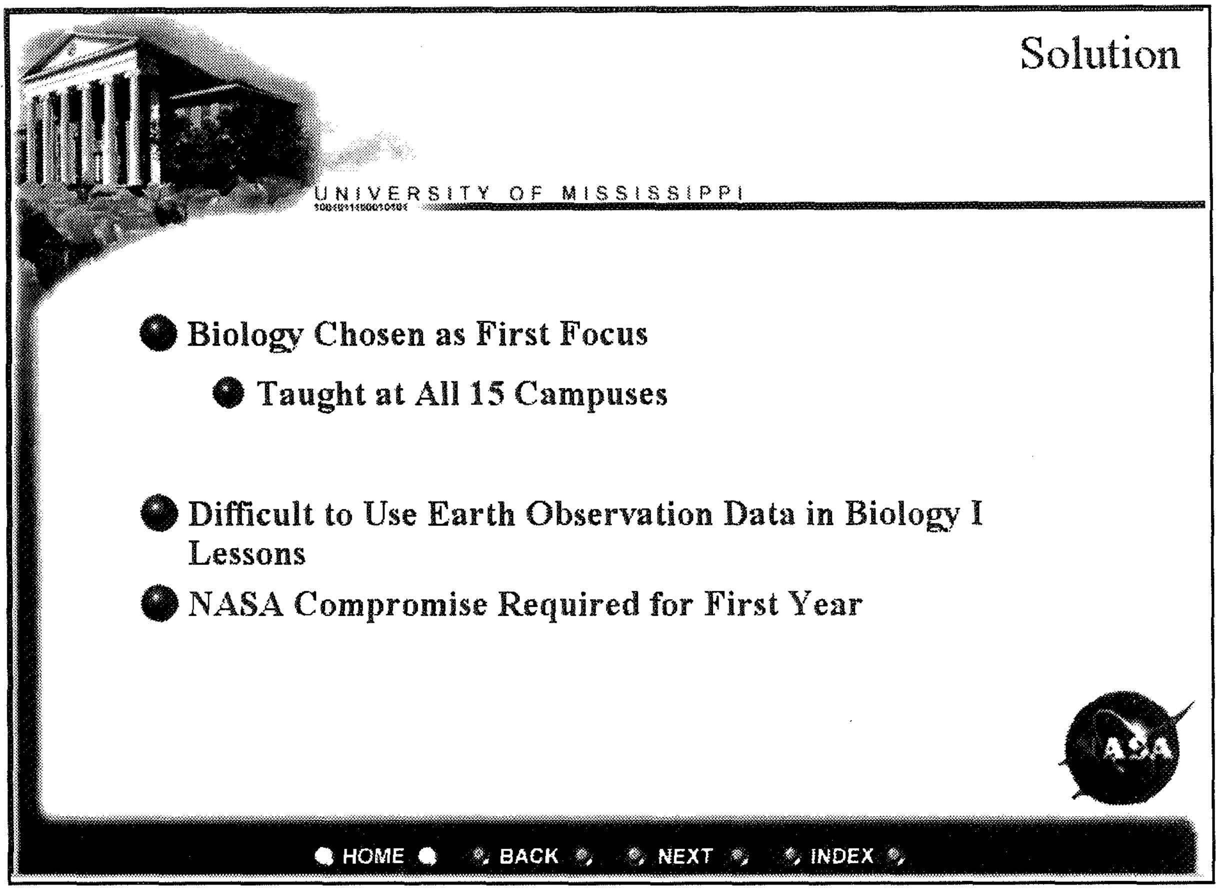
Problem

When first introduced to the concept the teachers were understandably reluctant. They already had very heavy, prescribed work loads and most of what they had to do did not include NASA data. Teacher cooperation became a first goal. The second goal was effective use of NASA Earth Observation Data at every campus.



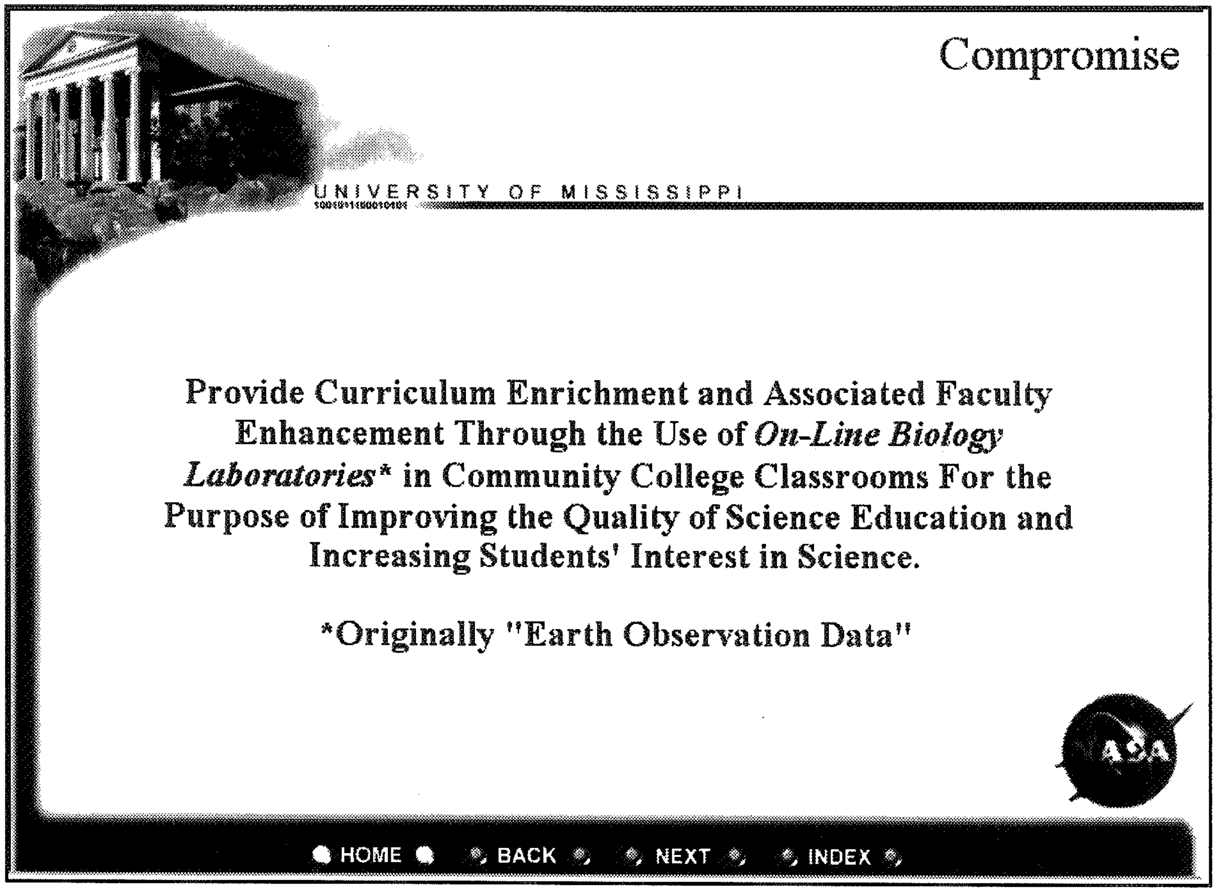
Solution

Some compromises had to be made. The goal became to create a methodology or system that could be used on every campus and that the teachers would use. First year Biology was taught from a state-level prescribed curriculum on every one of the fifteen campuses. However, using Earth Observation Data in that curriculum was difficult. A compromise was made that allowed us to focus, in the first year, on the lesson hosting and creation process.



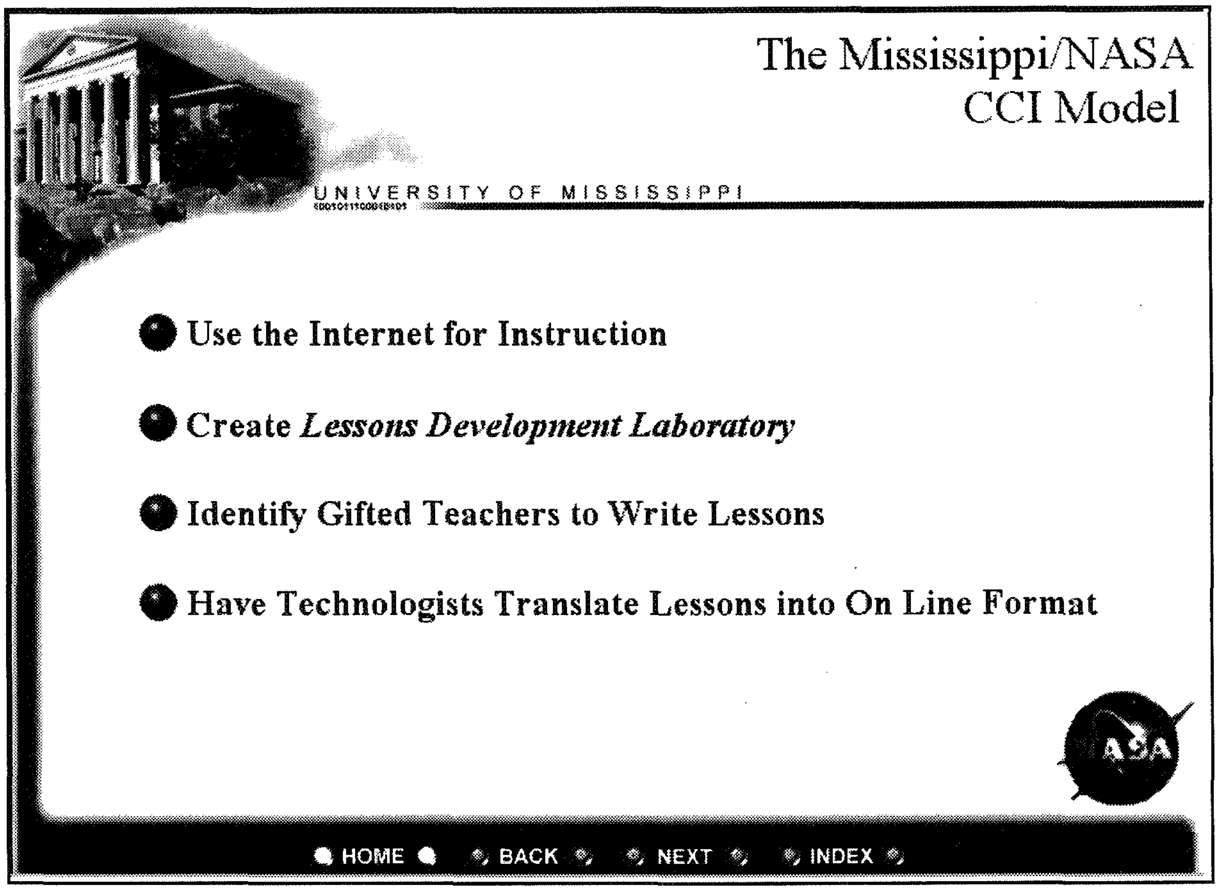
Compromise

The wording of the grant was then changed so that the purpose was the "use of On-line Laboratories" instead of "Earth Observation Data." In the second year the shift was made to use "Earth Observation Data," and the classes changed from Biology to Physical Science. Physical Science is taught at nine of the fifteen colleges and its curriculum is not prescribed with the same rigor that Biology is so the effective use of the labs is decreased somewhat.



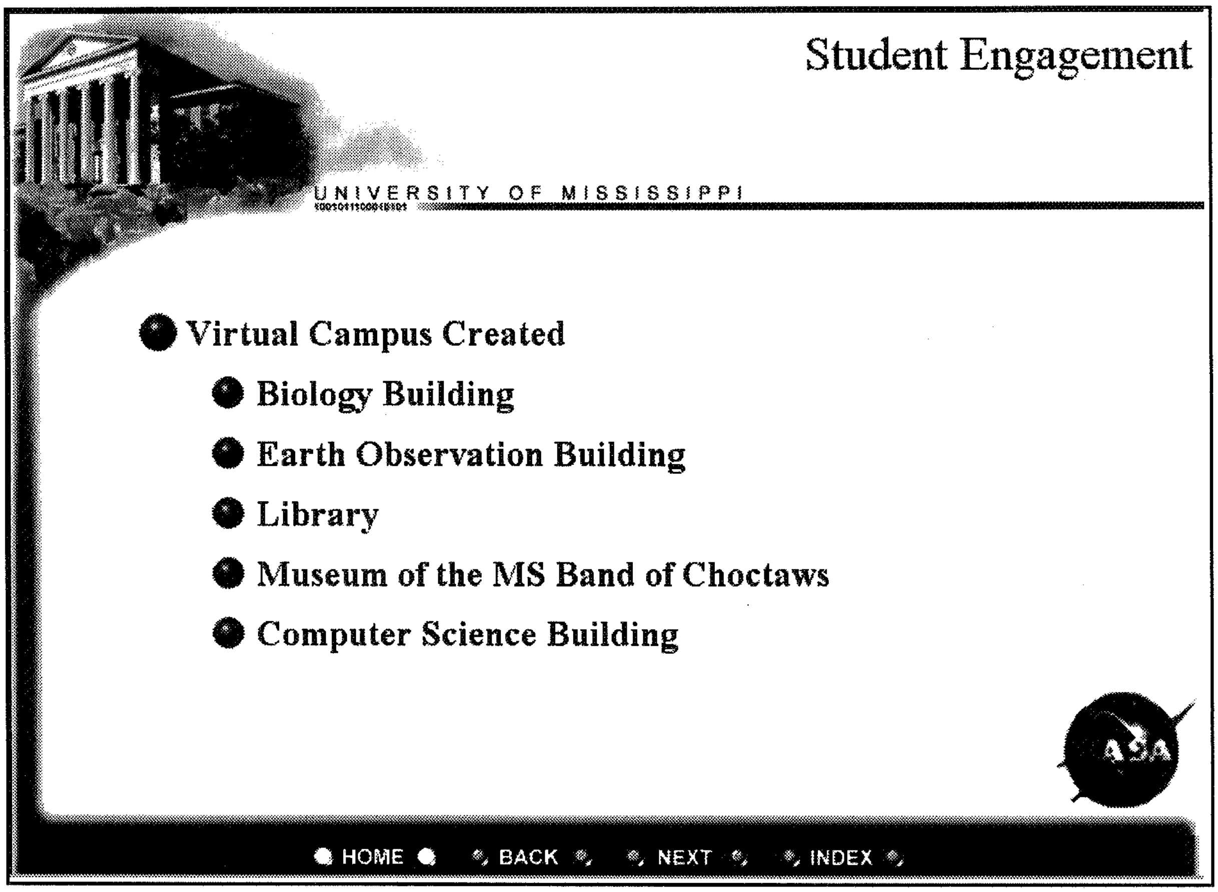
The Mississippi/NASA CCI Model

The model required the use of the Internet for lesson delivery but the focus was on low bandwidth delivery of the lessons. Many of the students involved were living in remote sites around the state so creating lessons that they could access remotely, using at the time 28.8 modems, was desirable. Another goal was to relieve the teachers of any technology mastery, so a laboratory was created to allow the Computer Science Department to convert the lessons to on-line episodes. Gifted teachers were identified by polling the current teachers. A workshop was then held for these teachers simply to demonstrate the possibilities that the new technology offered them. A communication system was created between the gifted teachers and the lesson development labs.



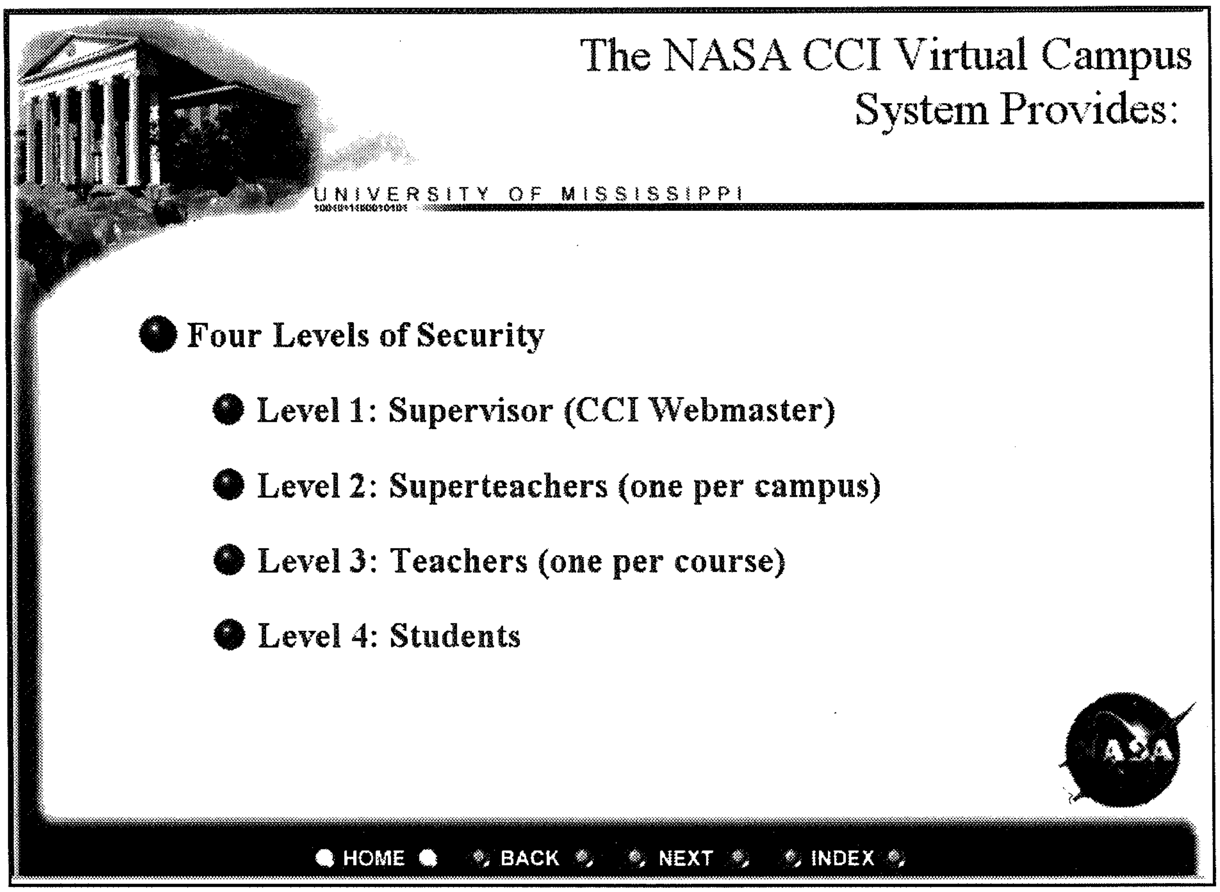
Student Engagement

The VRML campus was created. This required extensive experimentation in an effort to keep the bandwidth low. The first campus was filled with trees, flowers, highly textured buildings and walkways. These features were then reduced to maintain a "modem deliverable" three-dimensional campus. The first fully functional building was the Biology building. It still is rather stark but as the state backbone is completed it will be re-textured to be deliverable on the Internet directly. The current campus includes access to the Earth Observation building, the Library, the Museum of the MS Band of Choctaws (created by their eighth grade students) and a Computer Science building.



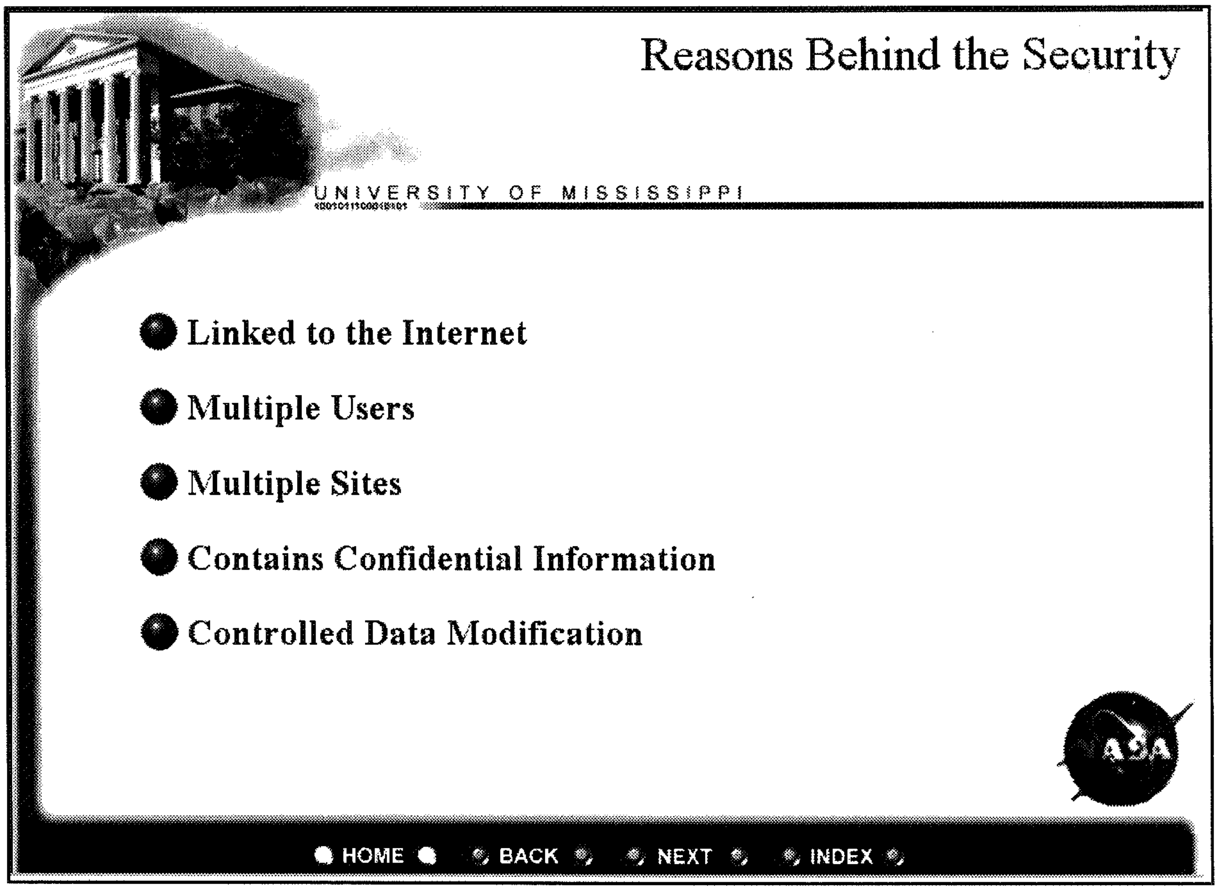
The NASA CCI Virtual Campus System

Once the campus was up and running and ready for on-site testing, security became a consideration. Since one of the original goals was to reduce the teacher workload, we had to include ways to acquire student performance data that was "teacher-free." This was done by creating a series of databases for each campus and within each campus for each class. Then, security features were written to allow access to the databases at different levels: Webmaster, Local Campus Administrators, Teachers, and Students.



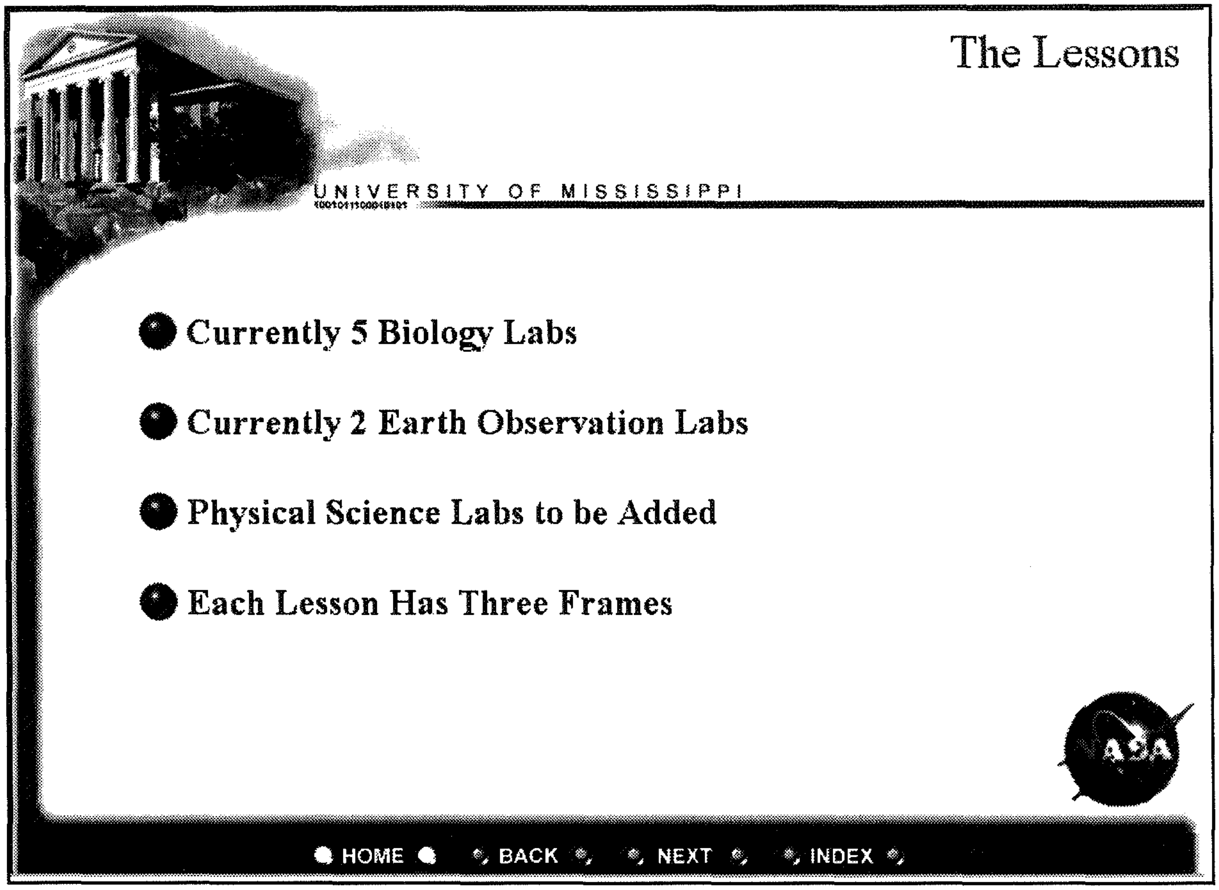
Reasons for Security

The remote access so necessary to the project created its own set of security problems. Since all lesson delivery was via the Internet, the security issues involved using different browsers had to be addressed. Multiple users from multiple sites created another set of security risks. Since all student performance data was highly confidential, a set of security measures was introduced to make sure that only appropriate students had access to the system. Each time a student took a test, the test was generated randomly for a set of questions sorted by difficulty level. The teachers dictated how many questions each student had from each difficulty level and from each question type.



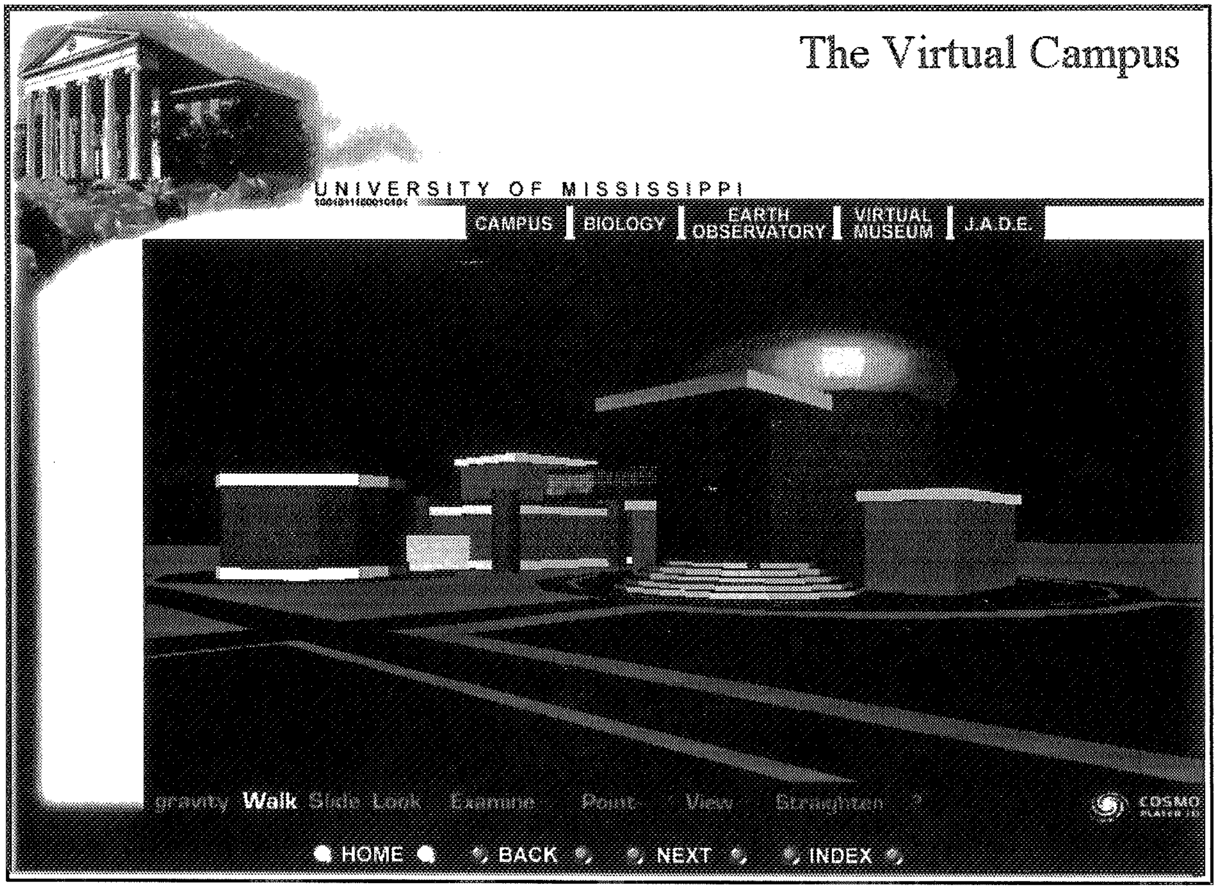
The Lessons

The campus currently hosts five Biology labs and two Earth Observation labs. Other lessons are in the creation process. Each lesson uses three frames. The use and layout of the frames is the total responsibility of the creating teacher.



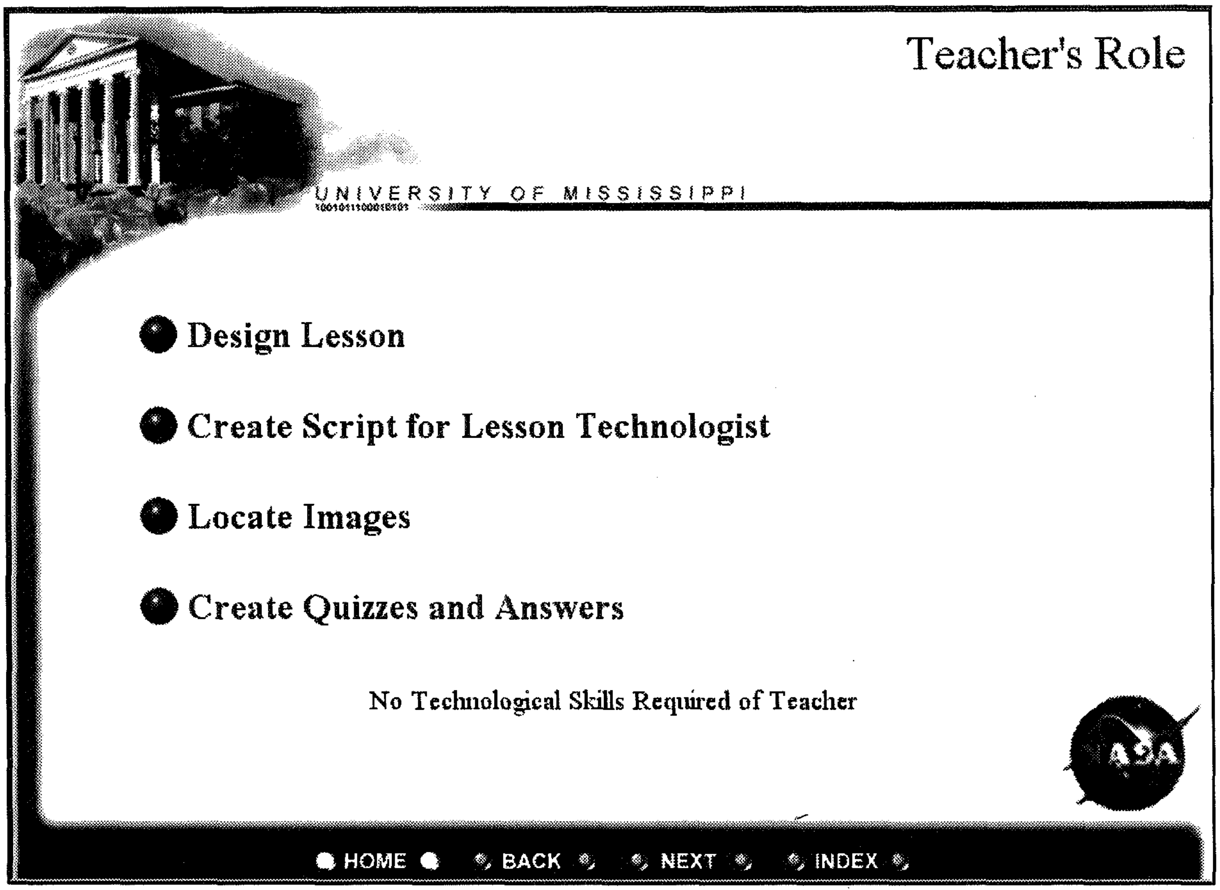
The Virtual Campus

The next few slides illustrate the actual "virtual campus" and allow the user to move around in the campus.



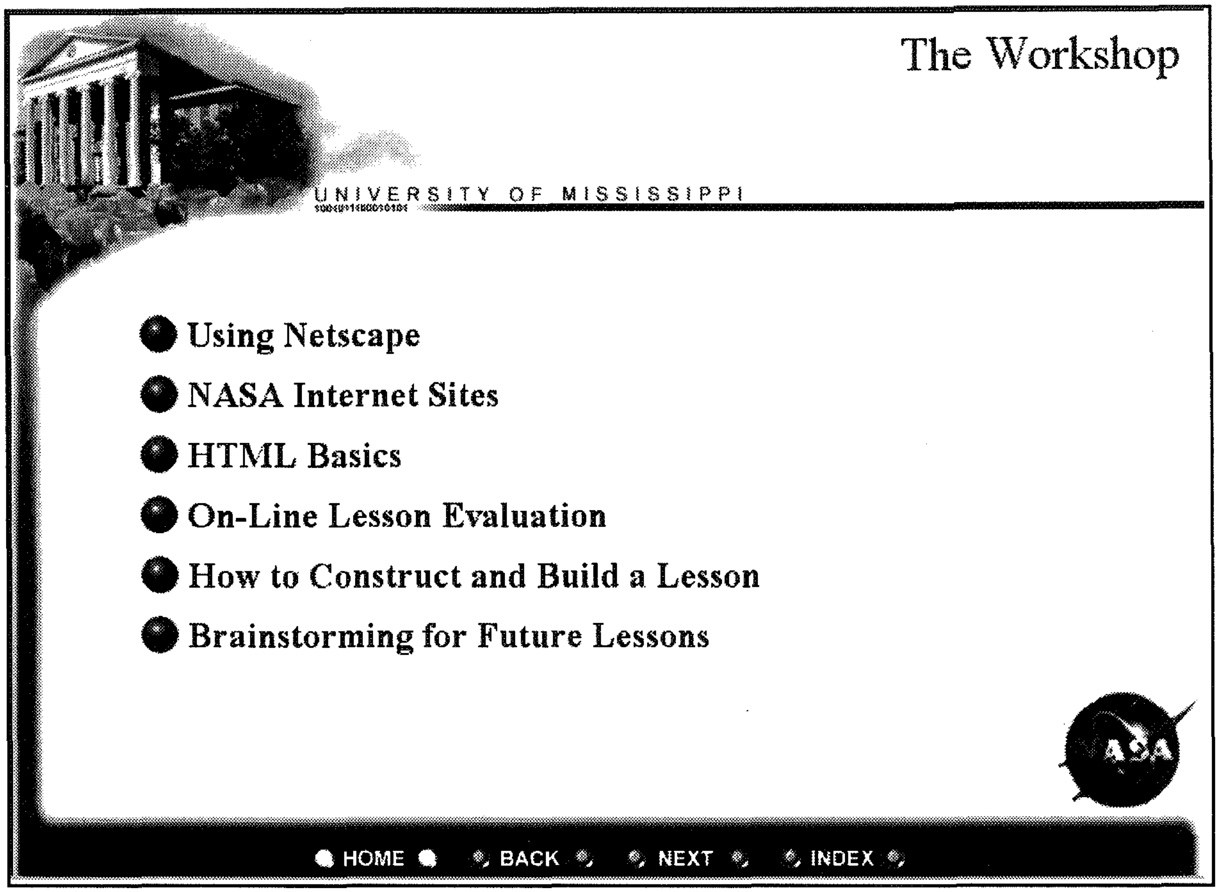
The Teacher's Role

The teachers are totally responsible for the content, layout, images, and testing for each lesson. The teachers create a script using a set of guidelines and questions created for that purpose. They then identify appropriate images and give them to the laboratory in one of many formats. They decide on the format of the testing for the lesson and provide a set of questions and answers sorted by difficulty level. It should be stressed that the teacher need not have any technological skills to have lessons created. (The State of Mississippi Community College Board has now adopted this method for the creation of on-line courseware.)



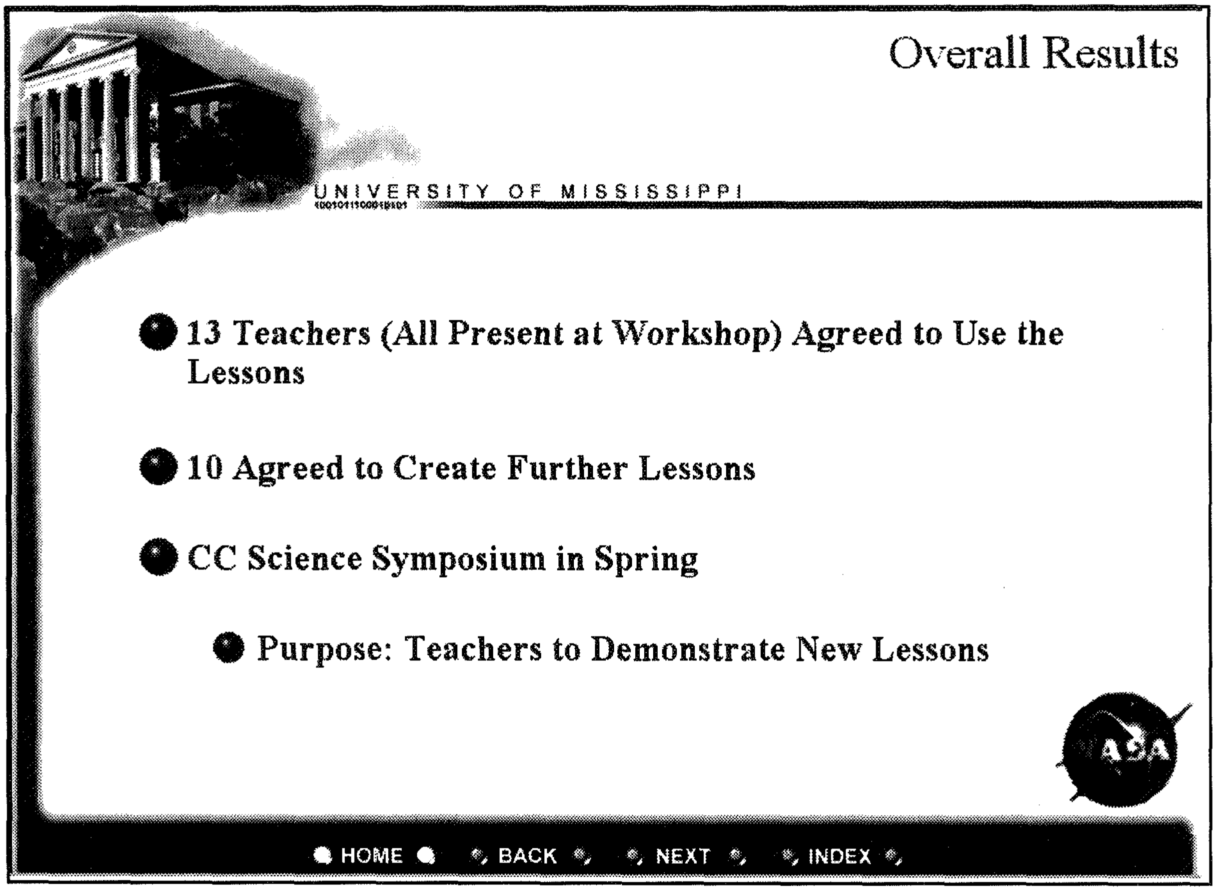
The Workshop

Once the first few lessons were created, a workshop was hosted for the fifteen schools. One biology teacher from each school attended. The teachers all had little or no experience using the Internet so the workshop included using Netscape, browsing NASA sites, HTML basics, on-line evaluation of the existing lessons, classes on lesson creation and finally, brainstorming for future lessons.



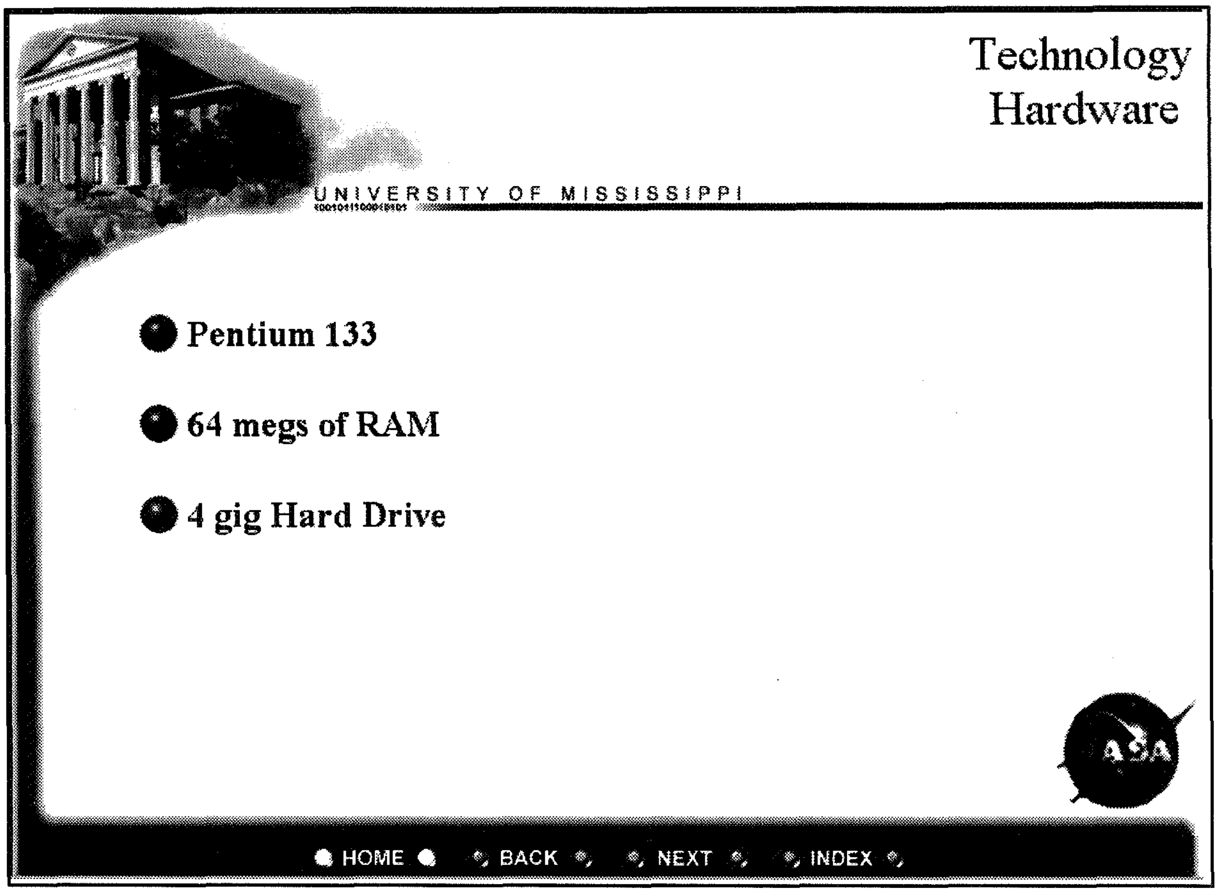
Overall Results

Ten of the thirteen participating teachers agreed to create future lessons. They also asked to have a Community College Science Symposium in the Spring to demonstrate their lessons to the other science teachers in the state.



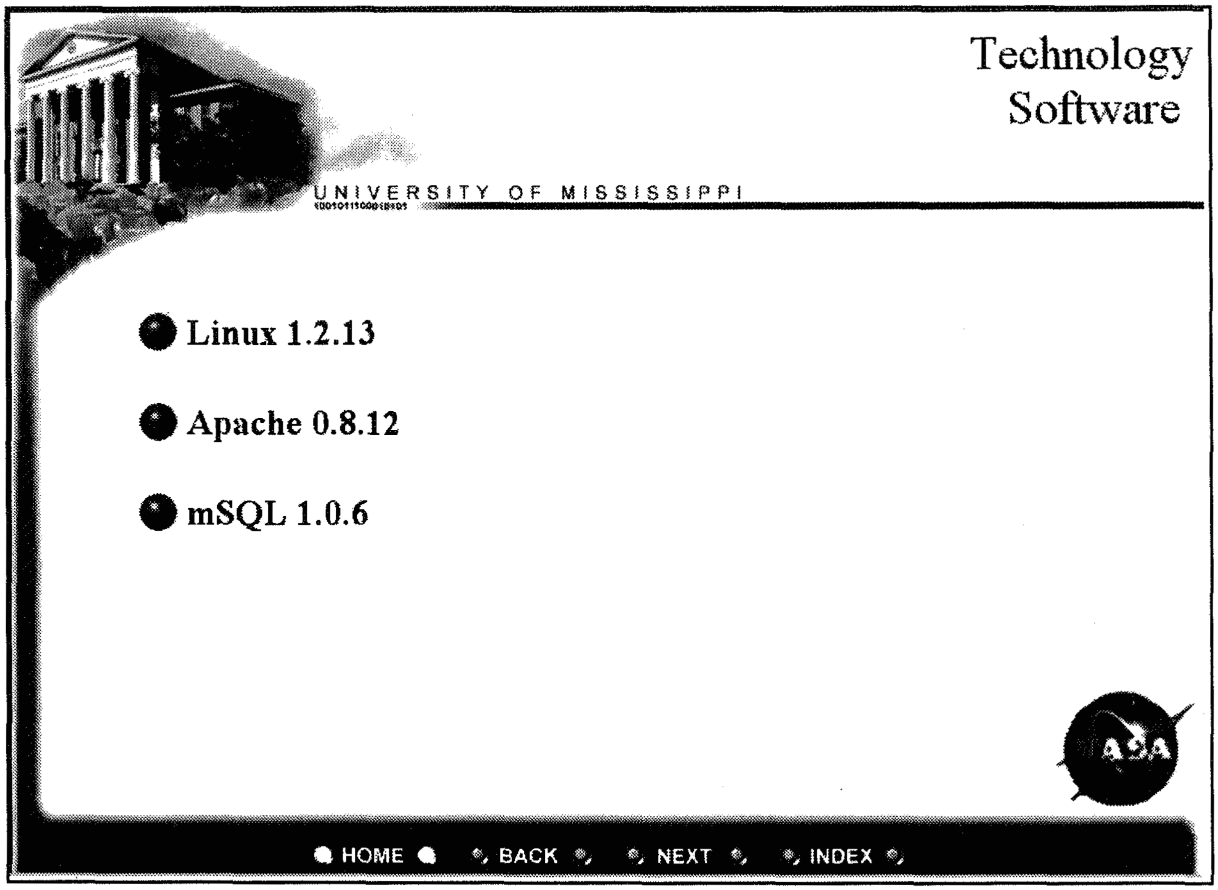
Technology, Hardware

Because Mississippi is one of the poorest states in the Union and because a majority of its population live in rural environments, the selection of the hardware and software had to be done with the idea of replication in mind. For that reason, all hardware used was off the shelf. The original machines were 133 MHz Pentium machines with 32 or 64 Meg of Ram. The campus can actually be run on a 486 machine running Win95 and 16 Meg. The large hard drive was for development only. It should be noted that all equipment used in the original project cost less than $10,000.



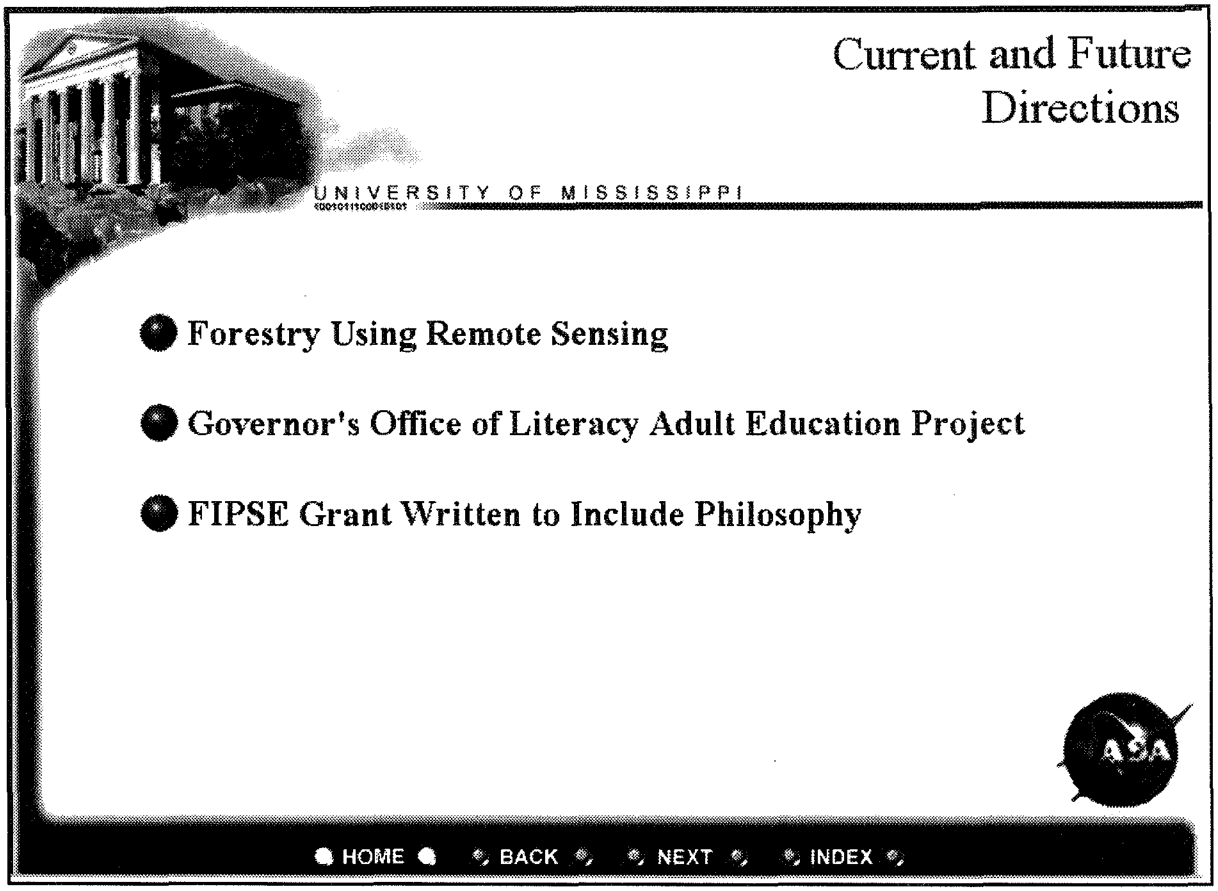
Technology, Software

The software used for the project was free. We used Linux for the OS, Apache for the server and mSQL for the databases. The campus was created using various versions of VRML. It can be viewed using older versions of Netscape with plugins or newer versions just as they come.



Current and Future Directions

The project is continuing in many directions. Currently, we are working with NASA on the commercial use of remote sensing data, creating training episodes for industry. We have a very active project with the Governor's Office of Literacy using on-line video conferencing to enhance job skills. Funding is being sought to expand the idea to include "virtual conversations" in the humanities.



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This document contains the proceedings of the Workshop on Advanced Technology for Engineering Education, held at the Peninsula Graduate Engineering Center, Hampton, Virginia, February 24–25, 1998. The workshop was jointly sponsored by the University of Virginia's Center for Advanced Computational Technology and NASA. Workshop attendees came from NASA, other government agencies, industry and universities. The objectives of the workshop were to assess the status of advanced technologies for engineering education and to explore the possibility of forming a consortium of interested individuals/universities for curriculum reform and development using advanced technologies. The presentations covered novel delivery systems and several implementations of new technologies for engineering education.

Certain materials and products are identified in this publication in order to specify adequately the materials and products that were investigated in the research effort. In no case does such identification imply recommendation or endorsement of products by NASA, nor does it imply that the materials and products are the only ones or the best ones available for this purpose. In many cases equivalent materials and products are available and would probably produce equivalent results.

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