

A CIVIL ENGINEERING MATERIALS COURSEWARE WITH A VIRTUAL LABORATORY

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Abstract

Concrete, steel and wood are common building materials. In Civil Engineering, a strength of materials course is usually mandatory at the sophomore or junior level. Students are taught the basic characteristics of these materials and then conduct laboratory tests to measure these characteristics, especially strength and deformation. This paper describes one module – a steel module – of a suite of multimedia civil engineering materials courseware modules that used modern communication technologies to educate undergraduate students anytime/ any place. A virtual laboratory is included in the courseware that allows the student to conduct virtual laboratory tests on steel in tension, in torsion and impact. A universal testing machine capable of applying tension, compression and torque, and a Charpy V notch impact testing machine are simulated. The courseware utilizes interactive animations, sound and graphics to enhance learning and retention, and improving the connection between theory and experiment. The modules are geared to active learning and include electronic quizzes for assessing short-term knowledge retention. The virtual laboratory is intended to prepare students for the real test, to supplement and complement the hands-on experience, to extend the range and convenience of testing, to test a student's prior knowledge, to guide the student through the testing and to allow the student to prepare and interpret the test results. Throughout the courseware, the student can monitor her/his performance and seek on-line help.

Introduction

Building materials have always been important to living organisms. Humans have used a variety of building materials for protection from natural forces and invaders, and for industrial and cultural purposes. Concrete, steel and wood are common building materials. To use them safely and efficiently to satisfy engineering needs require knowledge of their strength and deformation properties. In Civil Engineering, the characteristics of these materials are taught in a strength of materials course that is usually mandatory at the sophomore or junior level. Often students from other engineering disciplines, e.g. mechanical engineering opt for this course. In addition to conventional lectures, students normally conduct laboratory tests to measure engineering properties of materials. For example, students will study the desired properties of concrete for

various types of jobs, learn how to design a mix to provide the desired properties and then conduct laboratory tests to determine whether the desired properties have been achieved. The strength of concrete increases markedly with time within the first 28 days. The desired strength tests should be conducted at 7, 14 and 28 days but because of time constraints only 7 days test are often determined. Rarely, do students get to explore “what-if” situations because of the substantial time required to prepare a concrete mix, cure the concrete and test it.

The production of concrete and other building materials is also important. In textbooks, a line diagram of a production plant or an image may be shown. For laboratory testing, equipment and laboratory space are required and the cost is often significant. For example, the cost of a machine to test the strength of steel is usually upwards of US\$100,000. The question that arises is “how can we enhance the teaching of strength of materials course and create an environment for active learning at minimal expense?” In this paper modern communication technologies are used to address this question. The physical, chemical and mechanical characteristics of steel for civil engineering purposes are used to illustrate how computer technologies can be used to enhance the teaching of strength of materials.

Course Characteristics

The objectives of using modern communication technologies are to create a courseware with (a) interactive animations that will teach students the fundamental properties of concrete, steel and wood, and (b) virtual laboratories in which students will conduct virtual experiments that integrate with the fundamentals. These virtual laboratories are interactive and replicate all the procedures that a student would normally perform in a real laboratory setting but allow for exploration, testing, evaluation and feedback. The virtual laboratory is intended to prepare students for the real test, to supplement and complement the hands-on experience, to extend the range and convenience of testing, to test a student's prior knowledge, to guide the student through the testing and to allow the student to prepare and interpret the test results.

Some key features of the courseware [1,2] are as follows.

- Clear and consistent instructional design. Each topic has (1) an introduction with real world connections wherever possible (2) a list of learning outcomes (3) key terms and definitions (4) questions to guide learning (tied to learning outcomes) (5) presentation of the course material (6) summary of essential points at convenient locations in the course material
- Intuitive user interface
- Interactive course material
- Electronic quizzes for assessing learning outcomes and feedback to instructors
- Digital videos of manufacturing process
- An electronic notepad for students to record notes, change and retrieve them at any time during a study session
- Virtual laboratories

Illustrative Example

User Interface: The user can access any one of the three course modules and then choose from a number of topics related to that module (Figure 1).

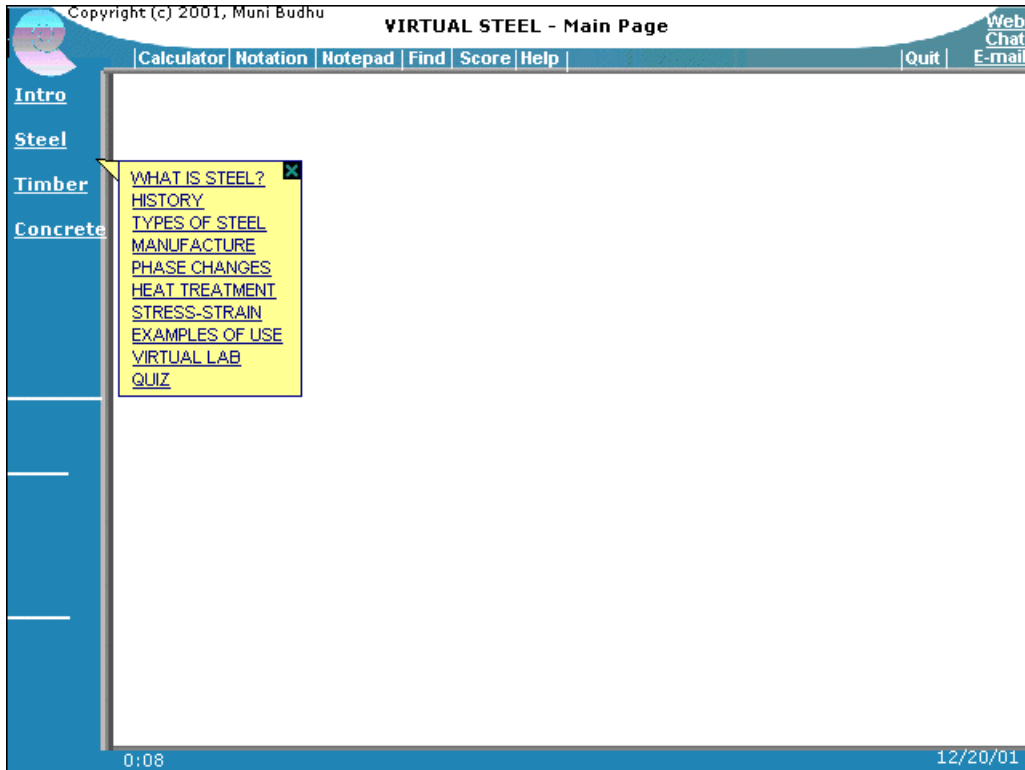


Figure 1 User access page

She/he can then proceed to learn about the selected topic as illustrated in Figure 2 for the topic 'TYPES OF STEEL'.

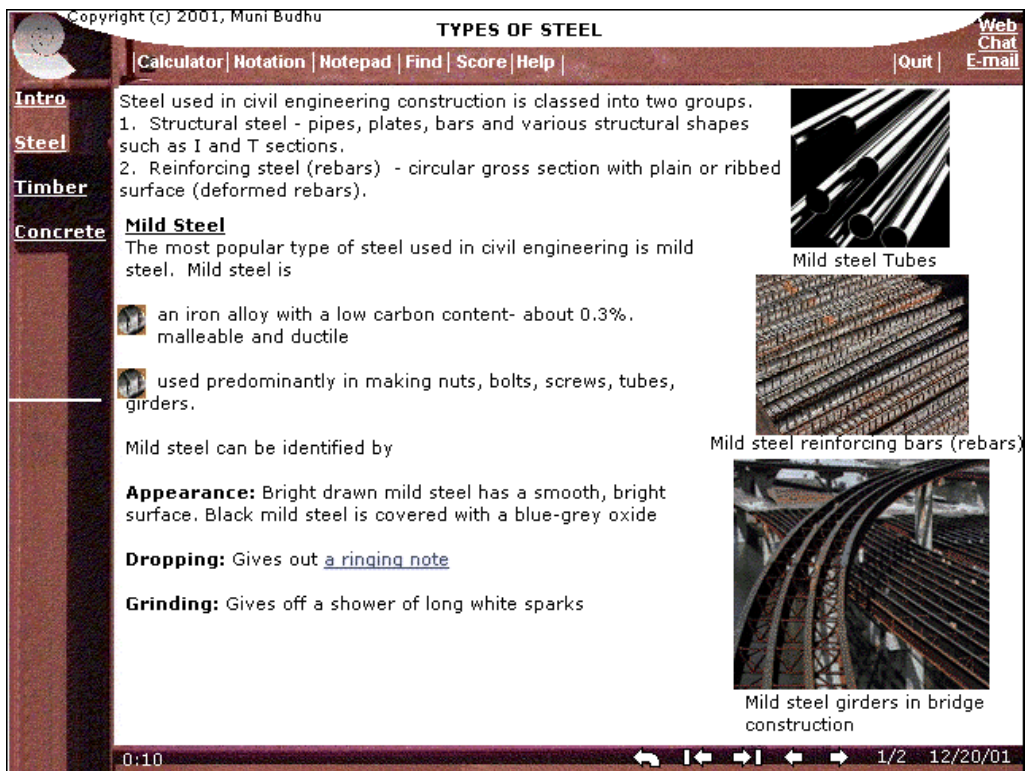


Figure 2 Learning about types of steel

Interactive Content: Wherever advantageous for learning, the content is created within an interactive environment. For example, the topic “PHASE CHANGES” (Figure 3) allows the user to explore each phase of steel by clicking on a phase and getting the desired information (Figure 4) while the base material is still available as a reference.

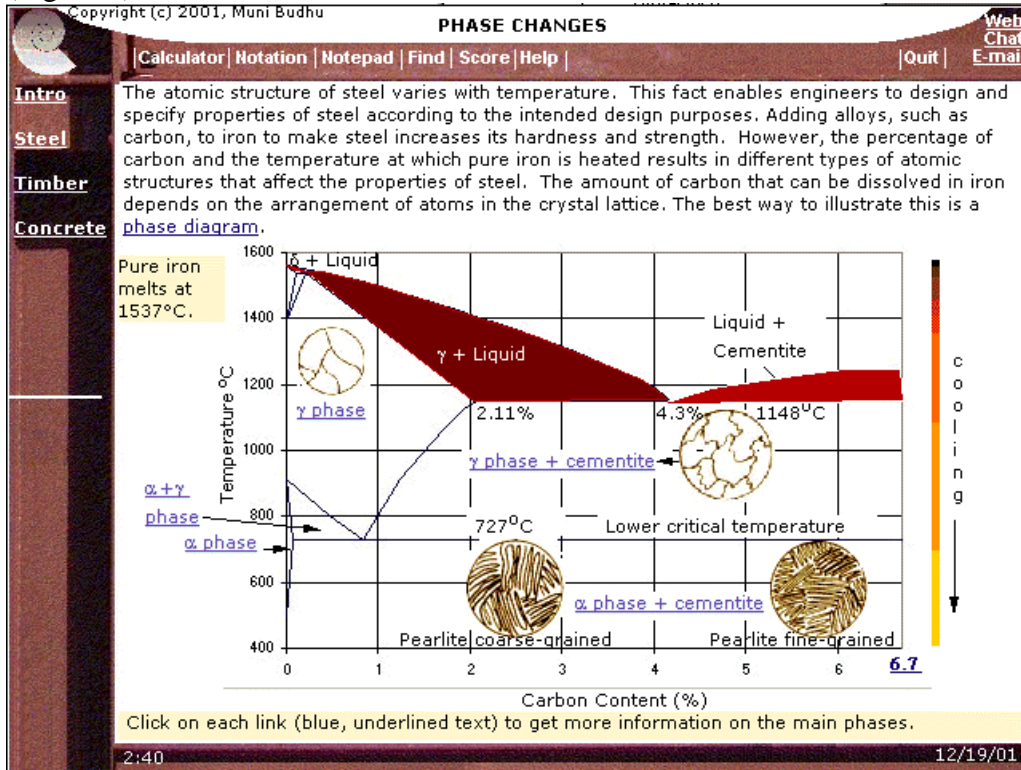


Figure 3 Learning about phase changes.

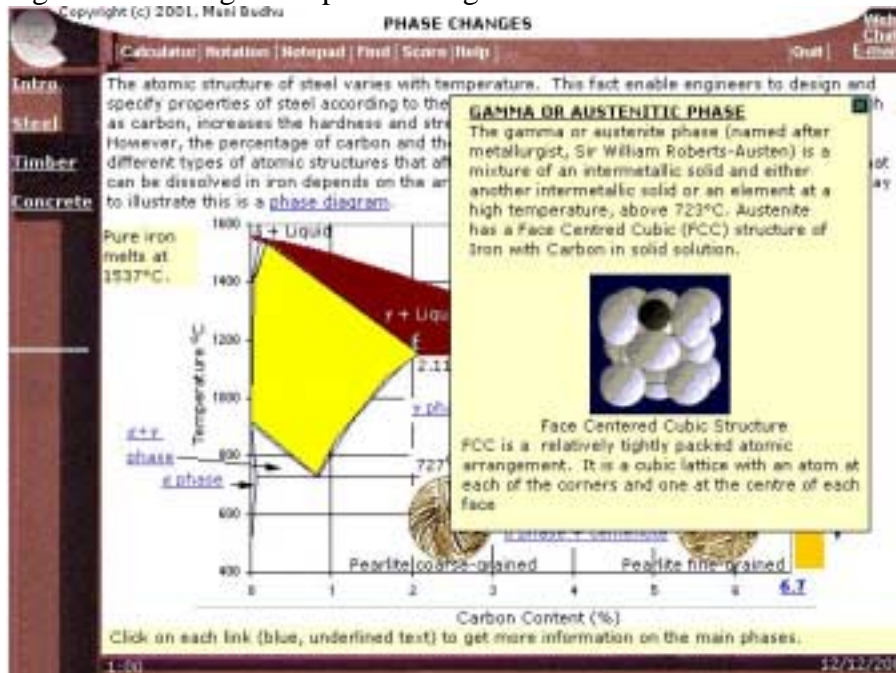


Figure 4 Accessing information at content level

Virtual laboratory: Each module (concrete, steel and wood) has a virtual laboratory with simulated three-dimensional apparatus with functional gauges and other instrumentation. Each student has his or her own virtual apparatus and his or her own test sample. A student can assemble the apparatus, prepare a test sample, place the sample in the apparatus, add loads, witness the deformation of the sample and extract properties from the test results. A virtual universal testing machine capable of applying tension, compression and torque to a steel or wood sample is shown in Figure 5. The user is prompted to identify key parts of his/her virtual apparatus to gain familiarity with them for later use.

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APPARATUS

Web
Chat
E-mail

Calculator | Notation | Notepad | Find | Score | Help | Quit

Intro
Steel
Timber
Concrete

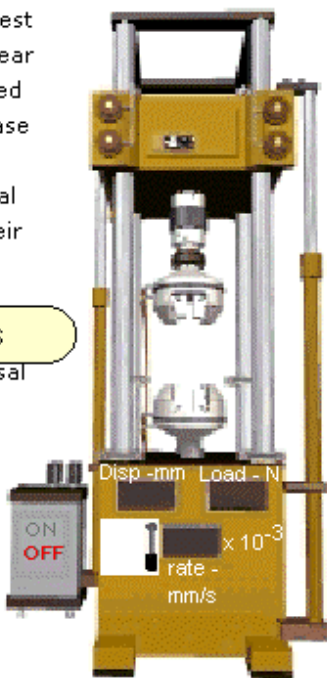
DESCRIPTION VIRTUAL UNIVERSAL TESTING MACHINE

The Universal Testing machine is a versatile device that can test materials such as steel and wood in tension, compression, shear and torque. This machine consists of a moveable head, a fixed base and a servo-hydraulic loading system. The head and base contains jaws (wedges) to grip the material. Most of these machines are computer controlled. Manufacturers of Universal Testing Machines usually have data acquisition software in their systems to automate the testing and extraction of desired material parameters.

TOP JAWS

You should identify the following parts for your Virtual Universal Testing Machine.

1. HEAD
2. TOP SET OF JAWS
3. BASE
4. BOTTOM SET OF JAWS
5. MOTOR CONTROL (ON, OFF SWITCH)
6. JAW LEVER
7. DISPLAY UNITS



Move the mouse over various parts of the apparatus to identify the main components. When you are done, you can move your mouse over the Virtual Lab on the side bar to proceed.

0:01 12/19/01

Figure 5 Identifying key parts of a universal testing machine

He/she is then prompted to select a test specimen and place it within the jaws of the apparatus (Figure 6). The user then sets up the apparatus, click on a switch to start the motor and observe the stress-strain relationship and the deformation characteristic of the material as illustrated for a tension test on a steel bar in Figure 7. The stress-strain relationship is obtained from curve fitting real test data and using the resulting mathematical relationship to establish the curve shown in Figure 7. A perturbation function is used to vary the mathematical relationship so that each student would have a different result.

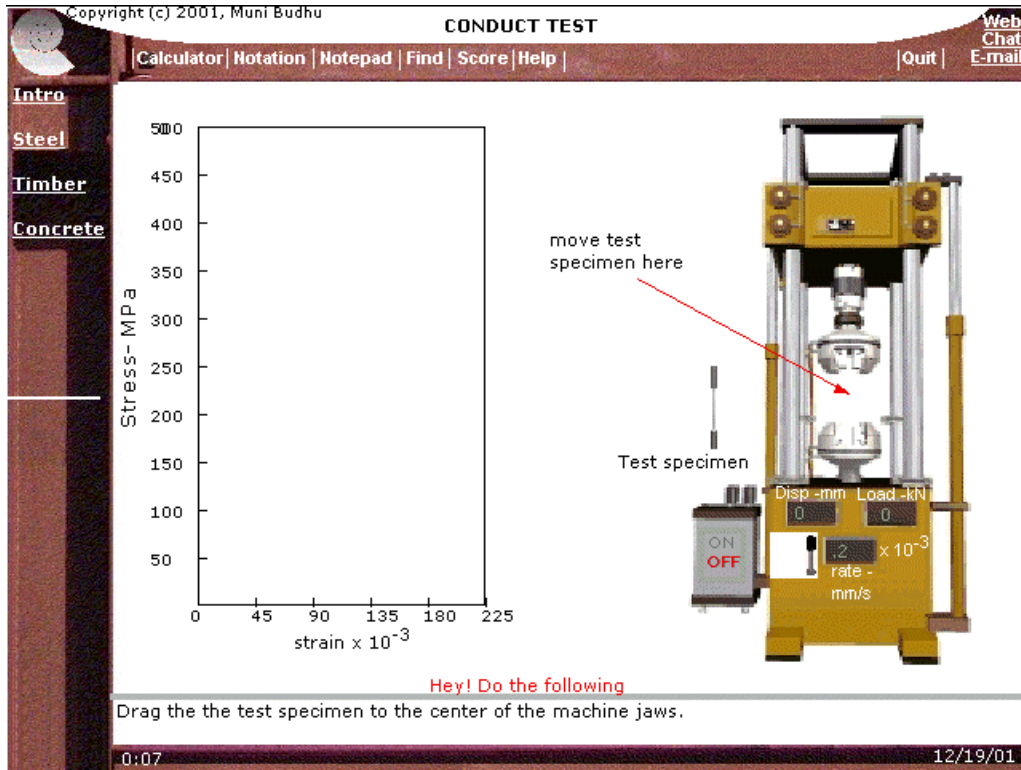


Figure 6 Dragging a test specimen within the jaws of a universal testing machine

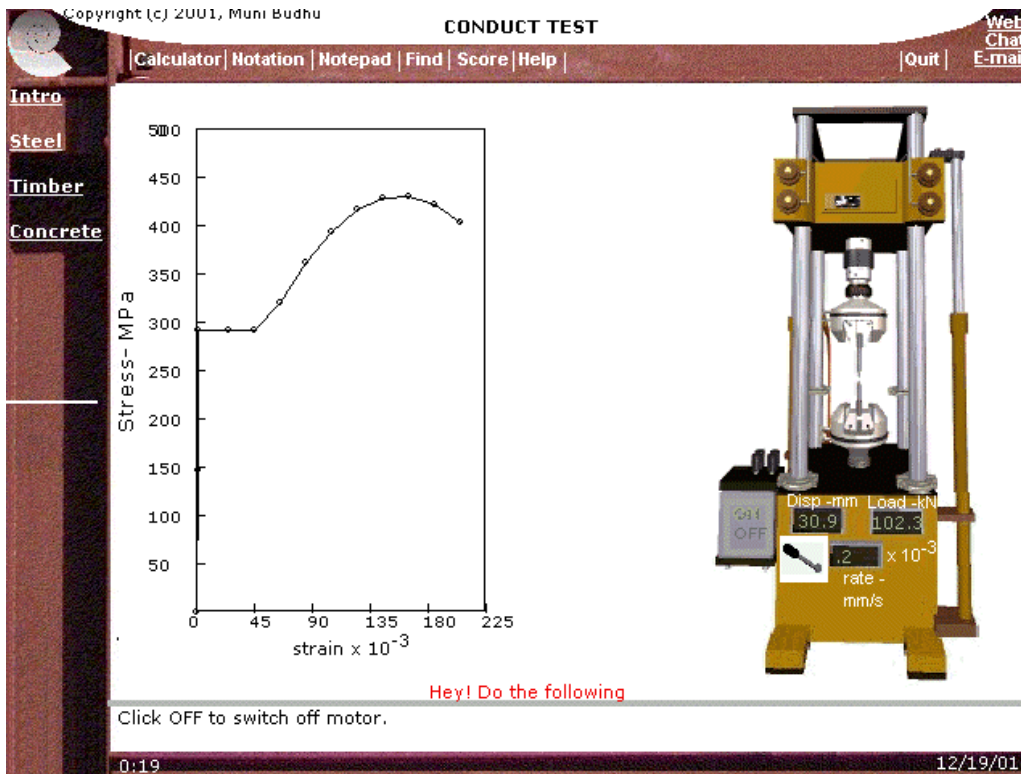


Figure 7 Stress-strain relationship and failure of a mild steel rod

The user is guided to extract the desired properties of the material such as, in the case illustrated, the ultimate, breaking and yield stresses. Using the yield stress and the strain at which yielding occurs, the user is prompted to calculate the Young's modulus of elasticity (Figure 8). The user answer is checked and if correct, he/she proceeds to explore the stress-strain characteristics other types of steel products. If the answer is wrong, the user has two more attempts before the correct solution is displayed.

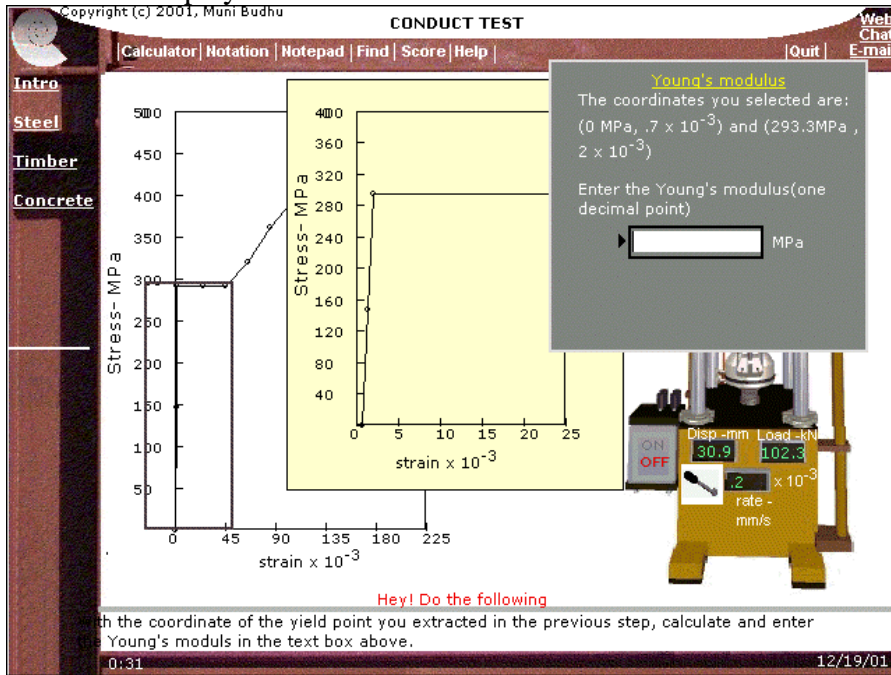


Figure 8 Calculation of Young's modulus of elasticity.

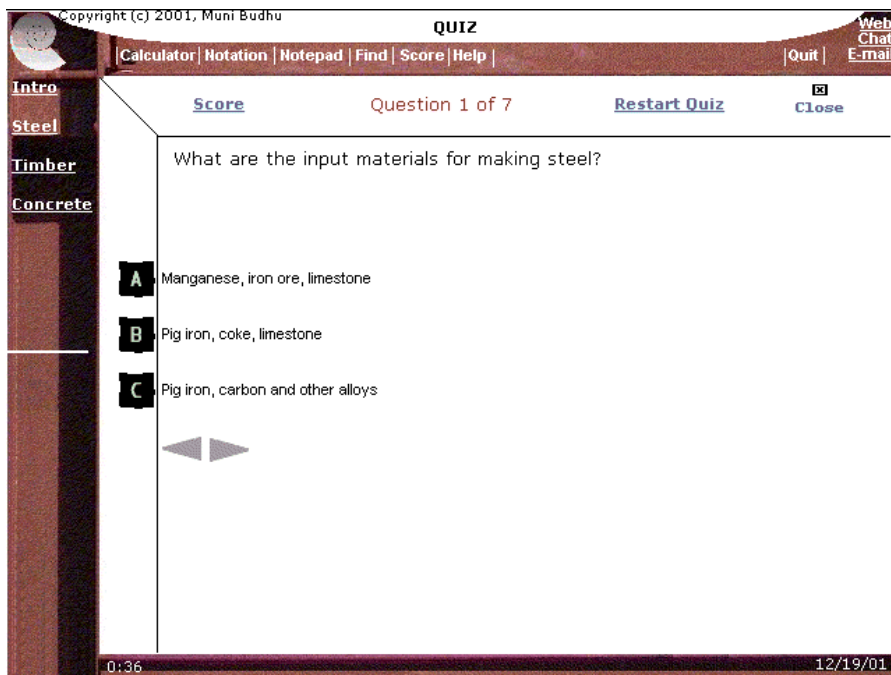


Figure 9 Quiz to test short-term knowledge retention

Short-term knowledge retention is evaluated using a quiz (Figure 9).

Potential Benefits

The potential benefits of the three modules are:

1. Enhancing understanding, knowledge retention and transfer of learning using visualization techniques
2. Active learning using interaction
3. Continuous testing of learning outcomes
4. Providing continuous feedback
5. Providing self-paced instructions
6. Providing feedback to the instructor on concepts that are not well understood so that remedial actions can be taken
7. Integrating basic concepts with virtual laboratories

These virtual laboratories have the potential to

- better prepare students for the real tests
- test skills and knowledge that are not currently tested
- enhance learning about laboratory procedures, interpreting of test results and applying the results to practical situations
- extend the range of testing
- allow for exploration and address “what-if” situations
- alleviate shortages of equipment, lack of equipment and inadequate space at some institutions
- enhance the connection among theory, experiment and application
- meet the needs of students in remote areas where experimental facilities may be absent or there is a lack thereof
- provide instructors with a tool to demonstrate in class the procedures of laboratory tests and interpretation of the results
- allow easy accessibility for some students with certain physical disability

Acknowledgement

The work described in this paper has been funded by a grant (DUE-0088613) from the Division of Undergraduate Education, United States National Science Foundation.

Reference

1. Budhu, M. (2000a) Interactive Soil Mechanics and Foundations, John Wiley & Sons, NY.
2. Budhu, M. (2000b) Soil Mechanics and Foundations, John Wiley & Sons, NY.

Biographical Information

MUNIRAM BUDHU is a Professor of Civil Engineering & Engineering Mechanics at the University of Arizona. He obtained his Ph.D from Cambridge University and serve as a Visiting Professor at St. Catherine’s College, Oxford University in 1995. Professor Budhu is working in the area of multimedia simulations for training, education and instructions, geomechanics and lattice modeling, and model-based simulations. He consults in multimedia training and course development.