The NSF Gateway Engineering Education Coalition Materials Project

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ABSTRACT

The Gateway Coalition Materials Project is a collaborative effort to improve the teaching of Materials Science and Engineering fundamentals and laboratory principles at the undergraduate level. The project develops multi-media, video and physical experimentation packages in modular form so that they can be used at a variety of schools and in a variety of settings. These include: (a) interactive, self-paced personal computer-based instructional modules on Fracture Mechanics, Corrosion, Electrical Conductivity, Scanning Tunneling Microscopy, Welding and Brazing, and Microscopy; (b) video-based virtual labs on Phase Diagrams, Tensile Testing, Charpy Impact Testing and Fractography, Heat Treatment of Steel, and others; and (c) innovative physical laboratory experiments and sequences. This paper is intended to help disseminate these modules and to report what was learned about creating these effective learning supplements.

1. INTRODUCTION

The Gateway Engineering Education Coalition is a collaborative program of 10 institutions, supported by the Engineering Directorate of the National Science Foundation. One focus of the Coalition is on improving "how we teach" as opposed to "what we teach." Teams of faculty from the various institutions have developed innovative approaches and learning tools for seven distinct curricular areas. One of these, the Materials Program Area team, is involved with the development of course materials for teaching material science and engineering at the introductory level within a topical range from atomic structure to materials processing. The two major thrusts in this area have been:

- **Solid State Materials Course Modules**
  The goal of this effort is to develop a course on solid-state materials to serve as a first course on materials science with emphasis on electrical, optical and related properties of semiconductors and metals. Specific objectives are to teach the principles of modern physics using state of the art experimental techniques and introduce students to the physics and engineering of solid state materials and electronic devices.

- **Introductory Engineering Materials Course Modules**
  The undergraduate engineering educational experience is enhanced when students get to “see and do” things that compliment classroom lectures. To provide these opportunities, this team develops exportable modules for teaching Materials Science and Engineering fundamentals and laboratory principles. The modular approach facilitates technology transfer to variety of schools and teaching settings. The “modules” include multi-media computer programs, videotaped demonstrations and hands-on laboratories.

One objective of this paper is to describe the multi-media and video-based modules that were developed for introductory engineering materials courses. Detailed descriptions of the hands-on laboratory experiments are not included here but can be obtained from the web site cited below. A second objective is to disseminate the results of numerous surveys of students who have used these modules. The summaries provided in this paper can provide some guidance to faculty who seek to develop effective learning tools.

2. SELF-PACED MULTI-MEDIA MODULES

2.1. About the Modules

Electrical Conductivity was developed by Dr. Linda Schadler while at the Department of Materials Engineering of Drexel University. In the multimedia module, electrical conductivity and the factors which affect it, in both metals and semi-conductors, are explained using text descriptions, animated graphics, and equations. The module can be downloaded from the web site in either Windows and Macintosh formats.

Corrosion of Metals was developed by Dr. Alan Lawley of the Department of Materials Engineering, Drexel University. In this multimedia module, three types of corrosion are explained using text descriptions, animated graphics, and equations. The module is available for download in both Windows and Macintosh formats. Figure 1 shows a detail of one screen from this module.

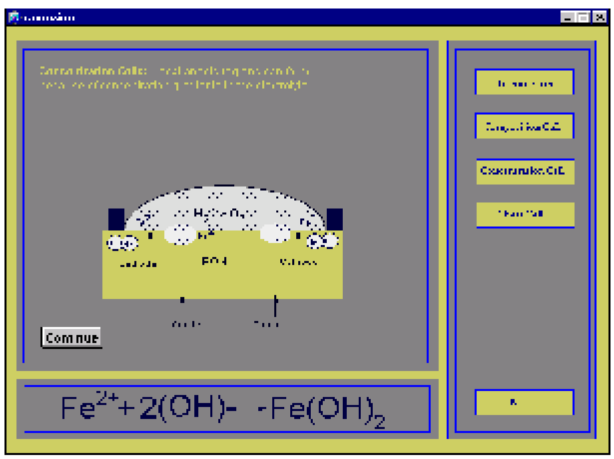

Figure 1. The Corrosion module is navigated by a window at the right of the computer screen. The main window displays a text description and a labeled animation of the corrosion processes. The chemical reactions in the bottom window change in time with the events of the animation.

Fracture Mechanics was developed by Dr. Alan Lawley, Dr. Surya Kalidindi, Dr. Linda Schadler, Mr. Sundararaman Narayanan, Department of Materials Engineering, Drexel University. In this multimedia module, fracture mechanics of materials is discussed using text descriptions, animated graphics, and equations. The module is available for download in both Windows and Macintosh formats.

Interactive Glossary for Engineering Materials was developed by Dr. Charles McMahon, University of Pennsylvania. The complete glossary is a CD-ROM product containing illustrations, animations, and video clips for learning materials science and engineering. The web site contains a demonstration version.

Optical Properties of Matter is a product of Dr. Gary Ruff and Mr. Sudararaman Narayanan, Department of Mechanical Engineering, Drexel University. In this multimedia module, the optical properties of matter are discussed using text descriptions, animated graphics, and equations. The module is available for download in both Windows and Macintosh formats.

Elements of Microstructure is an internet-based module developed by Dr. John Lannutti, Department of Materials Science and Engineering, Ohio State University. The module introduces the students to the microstructures of carbon steel, tool steel, stainless steel, aluminum, brass and zirconia, including high quality microstructural images. Specimen preparation and etching procedures are also explained. Another feature of the site is the use of embedded images. That is, regions of many micrographs can be clicked upon to reveal a higher magnification image of that region. This nicely simulates the experience of changing the objective lens on a real microscope.

Welding and Joining is a CD-based module developed by Dr. John Lannutti, Department of Materials Science and Engineering, Ohio State University. In this multimedia module, several types of welding, as well as brazing and soldering, are discussed using diagrams, animated graphics, and real world examples. The complete module is available for download in Windows format. A non-animated version is viewable through a web browser.

2.2 What We've Learned

All of the modules have been evaluated by the students of at least two universities. The approach of using graphics, animations and video to motivate the students to learn and to study other reference material appears to be a good one. From written student evaluations, we have found that one of the most important aspects related to the student acceptance of a multi-media module is the resolution and size of the images, movies or animations. The same students typically went on in their evaluation forms to say that they found the best part of the modules to *be* the illustrations. Most agreed that the pictures and the diagrams helped them to visualize the process much better. It is important to have text accompanying the images, but this text should be clear and brief. Many students felt that large amounts of text should be kept in hard-copy books. When these guidelines are followed, the multi-media module can be an effective tool for introducing topics of materials science and engineering.

3. VIDEO-BASED VIRTUAL LABORATORIES

3.1 About the Modules

Heat Treatment of 1040 Steel was developed by Dr. Charles McMahon, University of Pennsylvania. In this module, four steel samples are austenitized then quenched air, oil, water, or are furnace cooled. The students are able to see the entire experiment take place as if they could actually have participated. The directions, explanation, and analysis of result make this a video that can be understood by a person with no prior knowledge of this procedure.

Metallography is another video developed by Dr. McMahon. This module teaches the basic principles of how to prepare samples for metallography, what can be learned from metallography, and how the phases in the 1040 steel are affected by heat treatment. High quality microstructural images make it easy to see what the narrator was talking about.

Rockwell Hardness Testing was also created by Dr. McMahon. In this module, an experimenter demonstrates how to calibrate and use a Rockwell Hardness tester to determine the hardness of a sample. Included is a step by step walking through of how to take Rockwell Hardness measurements. An interesting facet is that the experimenter initially chooses the wrong scale, and then explains why a second scale must be chosen.

Casting and Phase Diagrams was developed by Dr. Jed S. Lyons, Department of Mechanical Engineering, University of South Carolina. In this video-based module, castings are made from aluminum-copper alloys. The effects of varying the alloy composition are discussed with respect to the equilibrium phase diagrams. The video and handout material includes sufficient detail to be used as a virtual laboratory experiment. Showing the 8-minute video in the classroom can also serve to motivate students to study phase diagrams. Figure 2 contains frames from the major sections of the video.

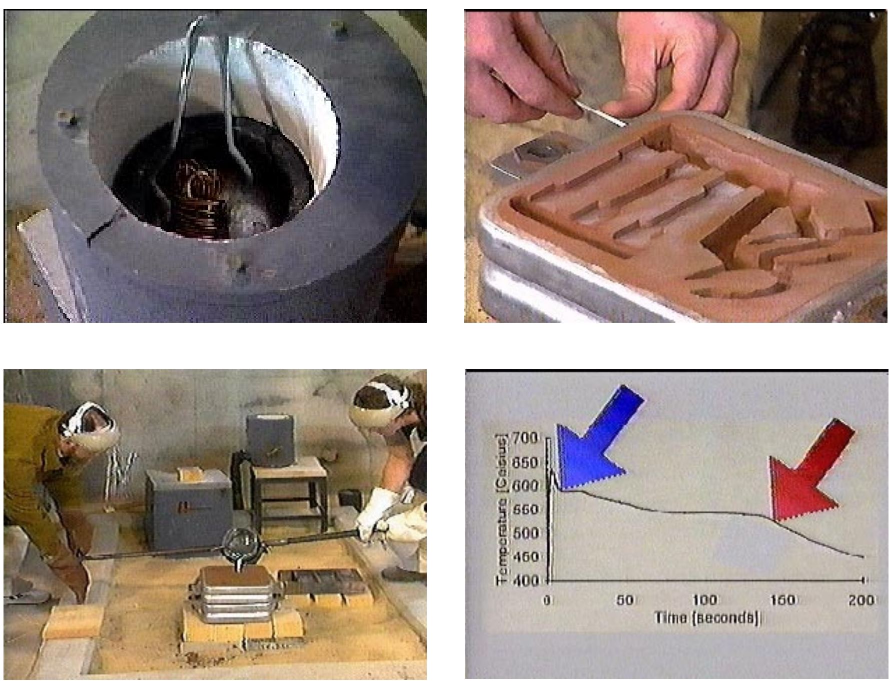

Figure 2. The Casting and Phase Diagrams video module combines industrial-style foundry operations with quantitative laboratory measurements. Demonstrated are the processes of making alloys from pure aluminum and copper, preparing a sand mold with thermocouples in the mold cavity, and collecting and analyzing the direct cooling curves of the solidifying alloy. Measured inflection temperatures are related to the liquidus and solidus lines of the phase diagram.

Tensile Testing: Small and Large Scale Deformation was created by Dr. McMahon to demonstrate how various materials respond to a tensile load and how this response can be used to generate a curve that provides important material information. It includes an explanation of the tensile test machine's operation and a detailed explanation of the load versus displacement graphs for the tensile tests.

Charpy Impact: Testing and Fractography was created by Dr. McMahon to demonstrate how 1020 steel changes from ductile to brittle as the temperature decreases. Segments include sample conditioning, mechanical testing and examination of the fracture surfaces with scanning electron microscope. By shooting the video on the SEM, with magnification and position changes recorded real-time, the students can learn a lot about the mechanisms of plastic deformation and fracture that they can not see with the naked eye

3.2 What We Learned

All of the video modules have been used and evaluated by the students of at least two universities. Many students reported that one of the worst things about watching a video of someone else performing an experiment is that it can be impersonal. If hands are seen doing the experiment but there is no face to go with them, only a free floating voice, then interest wanes. This can be remedied with an introduction showing the narrator/experimenter so they are not an anonymous. The videos where the student was able to see the experimenter received the most favorable reviews. Students really liked it when the video cut back and forth between the entire experimental set-up to the details of handling/testing the sample. Many other student comments dealt with the production of the video, as opposed to the topical content. Monotone voices, cheesy music, and jerky editing should be avoided. Relative to content, it was expressed that explanations of equipment, instrumentation and software should be detailed, but generic. In the words of one student "Watching someone else fill in a spreadsheet is almost painful." When these guidelines are followed, the video-based laboratory demonstration can be an effective tool for introducing topics of materials science and engineering

4. HANDS ON LABORATORY MODULES

A number of student handouts containing laboratory procedures and report questions from the Materials Project team are available for downloading from our web site. Table 1 is a listing of these titles.

TABLE 1. List of Laboratory Manuals Developed

Atomic Bonding and Arrangement*	Electrical Conductivity
Microstructure of Materials*	Tensile Behavior
Case Hardening and Diffusion*	Impact Behavior
Casting and Phase Diagrams*	Materials Degradation
Precipitation Hardening*	Fracture Toughness*
Hardenability of Steels*	Optical Properties
Stress Relaxation*	Scanning Tunneling Microscopy
Creep*	Multi-Axial Deformation
Flexure Deformation*	* now downloadable from web site

5. DISSEMINATION

The Materials project web site is http://www.ece.sc.edu/gateway/materials/gateway4.htm. It describes and/or provides download opportunities for most of the project's products.

6. ACKNOWLEDGEMENTS

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BIOGRAPHIC INFORMATION

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Gary Ruff is an Associate Professor in the Department of Mechanical Engineering, Drexel University.

John DiNardo is an Associate Professor in the Department of Physics, Drexel University.

John Lannutti is an Associate Professor in the Department of Materials Science and Engineering, Ohio State University.

Charles McMahon is a Professor in Department of Materials Science and Engineering, University of Pennsylvania.

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