Multimedia Virtual Laboratories for Introductory Materials Science Courses

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Abstract

"More real-world examples" is a frequent comment from students on course evaluations for an introductory materials science course at the University of Nebraska-Lincoln (UNL). Since students who are exposed to actual case histories remember concepts better and are more enthusiastic, we are developing virtual laboratory multimedia modules using Macromedia Authorware. The goals of this project are to expose students to real-world problems and to give them an opportunity to build on their knowledge to solve these problems. In each module, students are introduced to a materials-oriented case history and encouraged to run materials laboratory tests to understand the underlying problem. Each module includes a database of test results on several standard tests for several materials. After choosing which tests are appropriate for the case study, students will get instant results and will be encouraged to re-evaluate their options until they determine the cause of the problem. This discovery process allows the student to understand materials science concepts and materials laboratory tests more thoroughly and to appreciate how they can be used in industrial situations. Students also have the option of reviewing important basic concepts and the laboratory tests within the modules if they wish.

Introduction

"Elements of Materials Science and Engineering" is an introductory course in materials science at UNL. The course has been taught each semester for many years through the Mechanical Engineering Department. Although the course is primarily made up of junior-level mechanical engineering students (60-70%) who are required to take the course and accompanying laboratory, the class usually has several biological, chemical and industrial engineers who take the course as a technical elective. These non-mechanical engineering students are not required to take the laboratory part of the course and unfortunately, often find themselves at a disadvantage when it comes to understanding core materials concepts. The laboratory offers valuable hands-on experiences with concepts such as strength, hardness, fatigue, and techniques such as crystallography and x-ray diffraction, reinforcing many of the topics covered in class.

The disparity of understanding between students who take the laboratory and those who do not is apparent to students as well as the instructor. One recent end-of-semester survey had the following comment from a student, "Even though I study hard for exams, I sometimes found things seemed new to me. Seems like people with the lab did not have this problem." The development of multimedia virtual laboratories grew primarily out of an effort to expose these non-mechanical engineering students to laboratory exercises without requiring them to take the laboratory. In addition however, as the instructor I have frequently been disappointed with the lack of conceptual understanding even with the laboratory students. I find that the laboratory students become very good at getting the desired result from a particular laboratory exercise, but are not adept at solving open-ended problems involving several materials concepts. The virtual laboratories are an attempt to bring several concepts together and give students the opportunity to solve real-world problems on their own time and at their own pace and to see how materials tests might be used in real-world situations. The use of the multimedia environment also offers the advantage of interactivity and instant feedback - something that is not currently feasible in the class or laboratory environment.

The current laboratory exercises focus on a single concept each week of a 16-week semester. The topics covered are fairly standard for a materials science laboratory and include hardness, tensile testing, fatigue testing, sand casting, crystallography, x-ray analysis, solution hardening and cold-working. The students spend about 15-30 minutes listening to a graduate teaching assistant preparing them for what they are about to do. They spend the remaining hour and a half of the laboratory actually collecting data and then write up their results in a standard lab report format. The laboratory exercises are all well established and the activities are constructed to fit in the scheduled laboratory time.

The goal of this project is to supplement both the course and the standard laboratory activities with multimedia interactive virtual laboratories to develop a better overall conceptual understanding of materials science. Students will apply their previous knowledge and build on it to solve real-world problems. In these case histories, they will be presented with a scenario involving the failure or misuse of a materials part. They will be asked to envision themselves as professional engineers with extensive materials background hired to determine what happened. They first must decide what test to perform and will be able to choose from a list of standard materials tests: tensile test, fatigue test, impact test, hardness tests, microscopy (electron and light), and x-ray analysis.

This project's emphasis on active engagement with real-world problems is in line with education reforms in undergraduate science education. For example, the success of interactive methods in teaching students physics is well documented by Hake[1]. Physics departments around the nation have put tremendous effort towards physics education reform in the past several years. Dismayed by declining enrollment in physics courses and a lack of students' conceptual understanding of introductory physics material, physics faculty have put their efforts into revising and improving physics education. This effort has revealed some disturbing information. A study by Halloun and Hestenes[2] found that students rarely change their initial common-sense beliefs about motion and its causes in a conventional learning atmosphere, regardless of the quality of the instructor. Hence, performance is based solely on the student's preconceived notions where the passive lectures and end-of-chapter homework problems are used. Hake[1] later collected data from 6000 introductory physics students from around the country and showed that an interactive classroom is capable of, and frequently successful at, creating a conceptual understanding about motion. Similar results are suggested for engineering courses.

In addition to emphasizing a more conceptual understanding, the National Science Foundation (NSF) has highlighted several priorities in engineering education reform. NSF Acting Deputy Director Joseph Bordogna recently said, "I believe, however, that engineers must not only be the people who know how to do things right, but also those who know the right things to do. The latter is a much broader task requiring very different preparation and skills. Engineering is an integrative process but, for the most part, engineering education has not been conceived or taught as an integrative preparation."[3] In the same speech, Bordogna said, "We have been good at teaching the technical components of engineering education, but we have not necessarily taught them as connected or related to each other. And we have been clearly deficient in teaching the, what I would call, the 'sociology of engineering'. What do I mean by the term 'sociology of engineering'? To begin, engineers must be able to work in teams; they must be able to communicate effectively; they must be adaptable. They must also better understand their pivotal role in society in order to accept the responsibility of that role."[3]

In addition to striving for a more conceptual understanding of course concepts, this project is an attempt to address several of the concerns highlighted by Deputy Director Bordogna. The proposed virtual laboratories will require an integrated understanding of materials science concepts and hopefully lead to a more integrated approach to engineering in general. In addition, students will be working in collaborative groups where they must use communication skills with each other in order to reach a group consensus.

Virtual Laboratories

Several virtual laboratory topics are currently in development for this project. All topics will eventually be part of a complete software package. In this package, students will be able to choose whether to review certain general materials topics, review materials tests or jump right in to a case study. No explicit connections will be made between review topics and case studies in order to maximize the opportunity for independent thinking. Students will be assigned to groups and will be expected to find time outside of class to meet in the computer laboratory. Ideally, the student groups will be composed of several laboratory students as well as students not taking the laboratory so that all groups may benefit from knowledge gained in laboratory exercises.

One of the first virtual laboratories planned involves the case of a snowmobile accident. Figure 1 shows this initial screen. The group of students will read the accident report filed after a fictional snowmobile accident in which a snowmobile rider was killed. Through the story, they learn that the snowmobile rider lost control of his snowmobile shortly before crashing into a tree, killing the rider. A jury is now reviewing the case as the victim's family decided to sue the company for negligence. The students learn that a critical part of the steering mechanism on the snowmobile (the tie-rod) was broken when police investigated the scene. There are conflicting opinions about whether it broke before hitting the tree or as a result of hitting the tree (see figure 2). The snowmobile rider's family believes the tie-rod was improperly manufactured, breaking before the accident and causing the rider to lose control. In contrast, the company that made the snowmobile stands behind their product and believes the rider was driving recklessly. They contend that the tie-rod broke as a result of the impact with the tree. The judge reviewing the case asks the student group to comment on the situation as objective expert witnesses after performing some tests on the failed pieces.

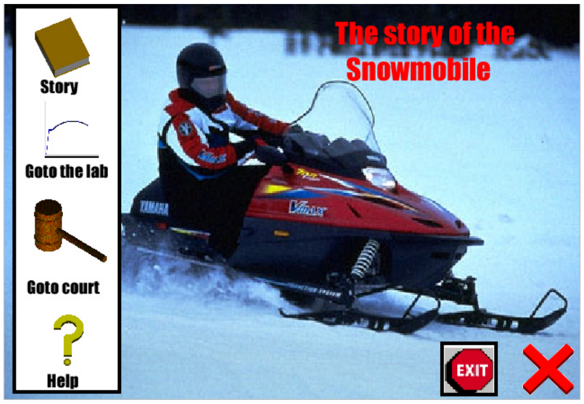

Figure 1 - Initial screen of the snowmobile story. Students may view the details of the story, go straight to the lab or present their findings to the court.

After reading and viewing this introductory information, the group may go to the laboratory. They may choose to review some basic materials concepts, such as hardness and hardenability, before deciding what tests to perform (see figure 3). In reviewing hardenability, the group will be reminded that a hardenability profile is primarily used for steels and demonstrates how easily the alloy forms a very hard and brittle martensite structure. The group will then choose a materials test, such as hardenability, review the information the test provides and receive instant feedback on the test results. Since the failed snowmobile part is steel and failed in a brittle manner, the group should realize that a hardenability test is an appropriate one to use to diagnose the failure. If the group performs the hardenability test, they will see that the particular alloy used by the snowmobile company forms the martensitic structure quite easily.

If the student group feels that this hardenability test has indicated the cause of the accident, they are invited to make a statement to the court. If not, they may pick another test to perform and

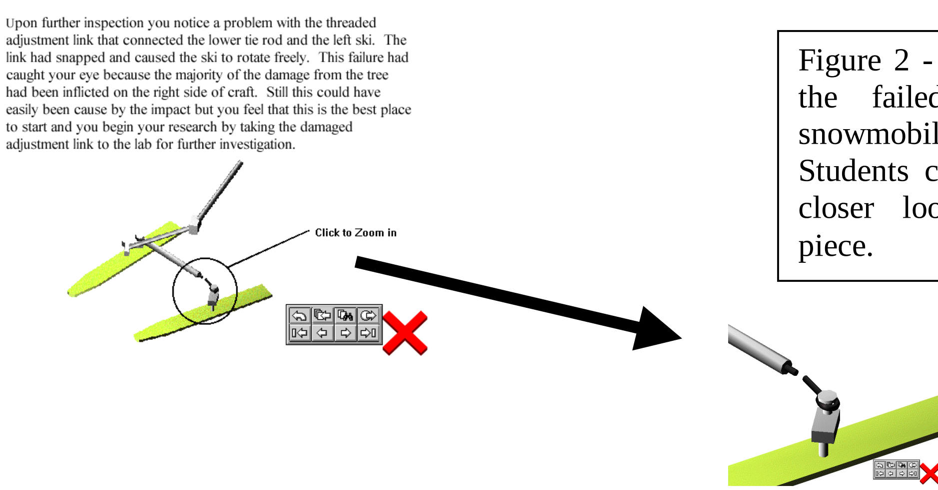

Figure 2 - Diagram showing the failed piece of the snowmobile accident. Students can zoom in for a closer look at the failed piece.

review before rendering an opinion. In order to confirm whether the group's opinion is correct, additional information will come to light when they offer their opinion. This information will make it clear whether the group's conclusions are correct. In the case of the snowmobile accident, if the group tells the court that the alloy used in the failed part is particularly susceptible to forming a brittle structure, further investigation will reveal that the company recently changed alloys without changing the processing technique. The old alloy was a steel with many different alloying elements (rarely brittle), the new alloy is a cheaper steel, made primarily of iron and carbon with few alloying elements (frequently brittle). This information confirms the correctness of the group's discovery. Hints will be given if the students get stuck.

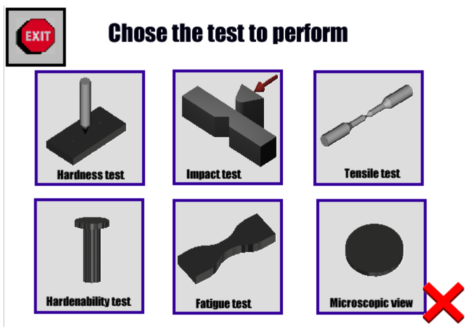

Figure 3 - The laboratory screen allows the students to choose a standard materials test to perform. On an earlier screen, students may review the basics of each test and what each test reveals.

All case studies will contain similar scenarios in which student group is to determine what went wrong with failed or misused materials. Some scenarios will involve court rulings, others will involve consultations from other professionals. Some of the other topics identified for case study virtual laboratories are: a broken wire cable (fatigue and solution treatment), copper light fixtures (cold working), steel nails (metallographic analysis, crystallography and x-ray analysis and scanning electron microscopy), broken marine engine bearings (impact testing) and solder (to study phase diagrams). Four of the topics listed, including the broken snowmobile part, are all currently in development and will be field-tested in the Fall Semester 1999. Results on using the new virtual laboratories will be reported in early 2000.

These virtual laboratories are planned as a supplement for all students taking the Elements of Materials Science course at the University of Nebraska. Student performance on these exercises will constitute a small, but significant part of their grade. The multimedia environment allows for easy record keeping and many grading options.

Conclusions

Multimedia materials science virtual laboratories are currently in development at the University of Nebraska - Lincoln and will provide introductory materials science students with opportunities to engage in real-world case studies involving materials science concepts. These case studies will provide a powerful way to reinforce basic materials science concepts and to encourage a more conceptual understanding of course material.

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