

# DEVELOPMENT OF AN INTERACTIVE WEB-BASED ENVIRONMENT FOR MEASUREMENT OF HARDNESS IN METALS

J. Hashemi, E.E. Anderson, and N. Chandrashekar

Texas Tech University  
Department of Mechanical Engineering

## Abstract

An interactive web-based experiment was designed as a preparation tool for students in the Materials and Mechanics Laboratory course at Texas Tech University. In the web-based experiment, the students were given an introduction to the concept of hardness, what it means, how it is measured, and the calibration and utilization procedure using a Rockwell tester. Two sections (eight groups) of the class were exposed to lecture but not to the virtual experiment and one section (three groups) was exposed to both lecture and the virtual experience. Each group was given a pre-lab quiz to assess their understanding of the concepts and objectives of the experiment. The groups exposed to the virtual lab were also given a short quiz on the procedure of the experiment. The pre-lab quizzes were graded without prior knowledge of the students' section or group affiliation. Grades were compared between groups that were exposed to both the lecture and the virtual laboratory and those groups who were only exposed to the lecture. The average grade of the students in the lecture and virtual laboratory groups was approximately 20 % higher than the lecture alone group with a p-value of 0.007 based on a t-test. The average grade on the knowledge of the procedure prior to actual experiment for the lecture and software groups was 75 on a 100 basis. Also, these students showed a great understanding of the hands-on procedure without significant input from the instructors. The lecture only groups did not have a good idea of the procedural steps and required significant guidance from the instructor. This research shows that the virtual lab can be an effective tool in preparation of the students for the actual experimental tasks in a laboratory environment. In this paper, the design of the software, important elements of the virtual lab and the evaluation results will be presented.

## Introduction

One of the most common impediments in the effectiveness of laboratory experiences in engineering curriculums is the lack of familiarity of the students with the specific equipment and procedures used in the experiments. Although the instructors of laboratory courses devote a great deal of time and effort to present the objectives, procedures, and the expected outcome of the experiments during lecture, the students are generally unprepared and do not recall the specific information during the actual experiment. As a result, a great deal of time and effort must be expended to refresh these concepts during the laboratory period. The problem becomes even more critical in cases where, due to a lack of equipment, experiments must be performed one group at a time. This is true of most equipment intensive laboratories such as Materials Science and Mechanics Laboratories. Because of the above problems, the laboratory experience is deemed ineffective and a frustrating experience by many students and instructors. If alternative student preparation methods are developed that assist the students to become

more prepared for the laboratory period, the instructor may use the laboratory more effectively and improve the overall quality of the experience. One approach to alleviate this problem would be to develop interactive software that maybe distributed to students via the internet (as a preparation tool and not as the replacement for the actual experiment) i.e. web-labs. The students may access the software at their convenience and become familiar with the objectives, procedures, and the expected outcome of the experiment in advance of the actual laboratory period. It is believed that the students' knowledge of the procedure and equipment will improve significantly when exposed to such tools and therefore the actual learning process during the laboratory process improves significantly. Clearly, the design of the software is very important and must be such that the students will access the information with ease and in a modular manner.

Recently, there have been numerous efforts in this direction in various fields of engineering. For example, Elsherbeni et al. developed one of the early virtual laboratories in microwave and electronics as purely a visualization tool (Elsherbeni et al., 1995). Some of the earlier efforts in the development of such tools in various engineering fields are those by Chevalier et al. in the mechanics area (Chevalier et al., 2000), Monter-Hernandez et al. in power electronics (Monter-Hernandez et al., 1999), and Avouris et al. in computer-assisted laboratory courses (Avouris et al., 2001). Some of the more interactive efforts are those reported by Bhanduri and Shor in the area of Controls (Bhanduri and Shor, 1998), Budhu in Soil Mechanics (Budhu, 2001), Schmid in Controls (Schmid, 1999), and Gustavsson in Electrical Circuits (Gustavsson, 2003). More recently, other educators have developed interactive software that can be offered to the students as laboratory preparation tool to become familiar with the procedure and equipments. Two such efforts are in Materials Science (Hashemi et al, 2003) and Experimental Methodology (Swanson, and Lynch 2003).

In this paper, our efforts in designing such a preparatory software tool for an experiment on determination of the hardness of a material are presented. The software was designed based on our experience with a previous module on Metallography (Hashemi et al, 2003) that was very well-received by the students at Texas Tech University. One focus of the paper is on determining and evaluating the impact of the software on procedure knowledge and equipment usage familiarity of the students.

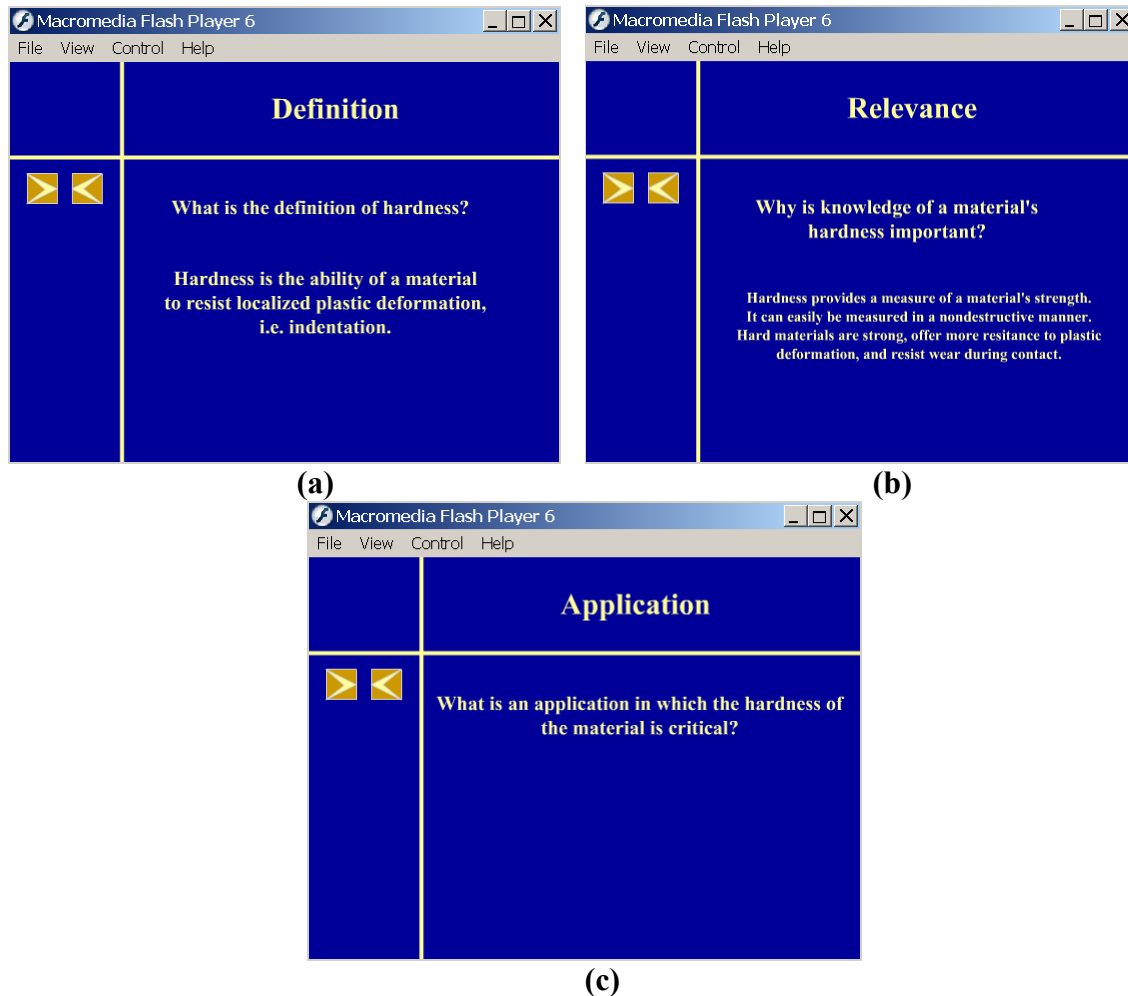
### **The Experiment**

The software was developed for the Materials and Mechanics Laboratory course ME-3328 offered as part of the Mechanical Engineering curriculum at Texas Tech University. Every semester, three sections of this course are offered with a maximum enrollment of sixteen students (four groups) per section. The students in each section are divided to four groups that will perform the experiments one at a time. One experiment that is performed in this laboratory course is the Hardness Experiment. In this experiment, the students will use a Rockwell Hardness tester to determine the hardness of various known metals. The equipment requires calibration prior to each test in a given scale. Under normal circumstances, in addition to the lecture material, the students are given a twenty-minute lecture during the laboratory period on the nature of the equipment, its various components, and procedure. The instructor then performs the first calibration process

and then allows the students to perform the hardness experiments. The process is repeated for every group. It is clear that a majority of the period is therefore devoted to the lecture process and there is not a significant amount of time for the students to perform other more meaningful tasks such as measuring the hardness in various scales and comparing the relative measures of various scales.

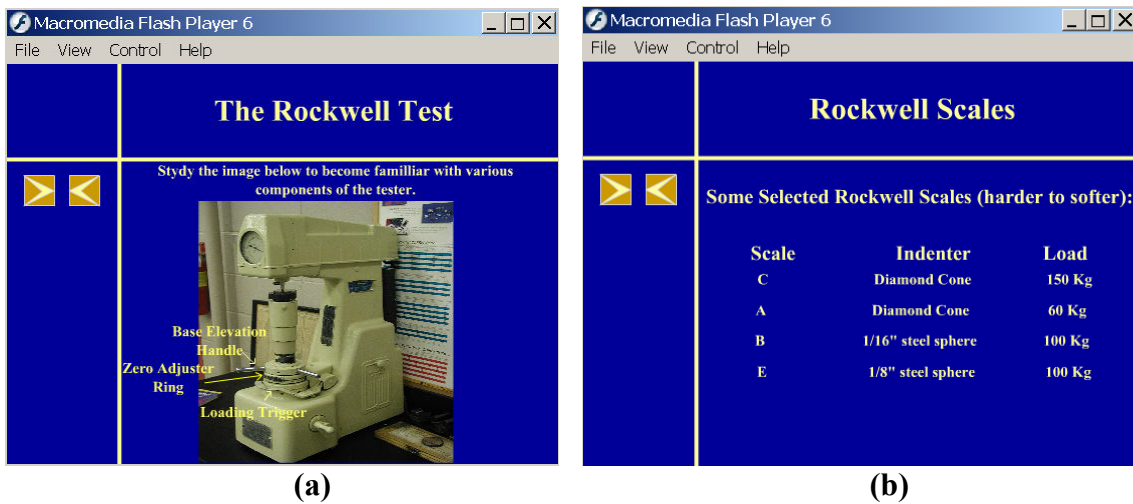
### The Web-Based Module

The authors developed an interactive tool for the students to become familiar with the objectives, procedure, and equipment used in this experiment. The virtual experiment was designed using the Macromedia Flash (Macromedia Inc, CA, USA) software. Video clips, images, and text materials were used in an effective manner to explain each step in the experiment. The module starts by introducing the basic definition of hardness Figure 1a, its relevance to materials selection and design Figure 1b, and its usage and application Figure 1c. The students step into the module by clicking on the forward arrow button after they have digested the information on the screen. The rewind button can be used to step back in the software and refresh one's memory of the contents of previous steps.



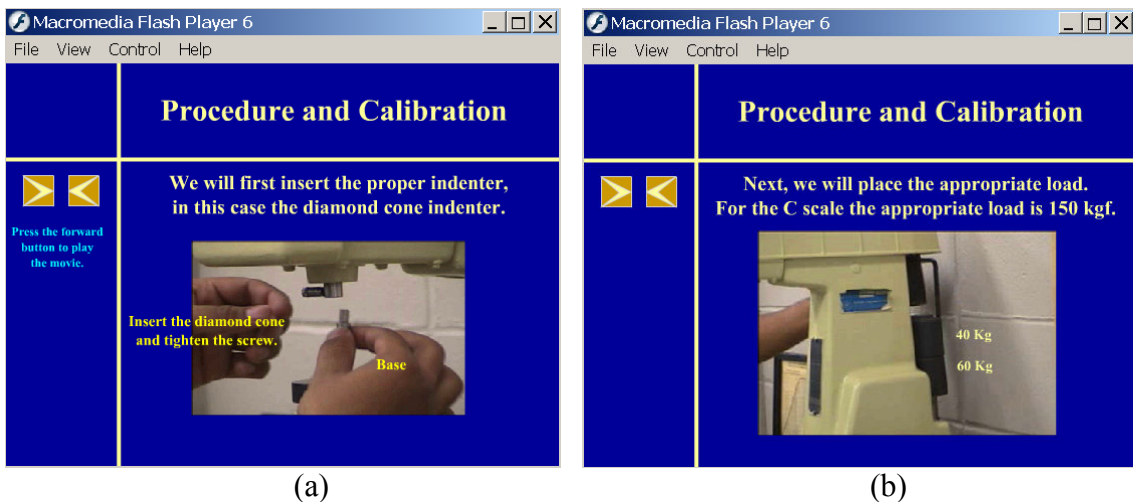
**Figure 1. Introductory stages of the experiment. (a) Definition of hardness, (b) Relevance of hardness, and (c) Usage and application of hardness.**

Various hardness tests and scales are then introduced and important concepts are conveyed. For example, when discussing the Rockwell hardness tester, the image of the tester is presented and various important components of the tester are identified. This gives the student an idea of what the equipment is and what are its important components and their proper names, Figure 2a. Various Rockwell scales are then presented noting the differences between scales, Figure 2b.



**Figure 2. The Rockwell hardness tester. (a) Its components and (b) various scales identifying the type of indenter and the amount of load needed.**

Once the introductory stage is completed, the calibration process is presented. The students are shown that for each scale, the tester must be calibrated using a calibration block of known hardness. The calibration process is then presented in a step-by-step manner using single and multiply synchronized video clips. The steps including selection and insertion of the proper indenter, Figure 3a, proper load, Figure 3b, and presented with video clips.



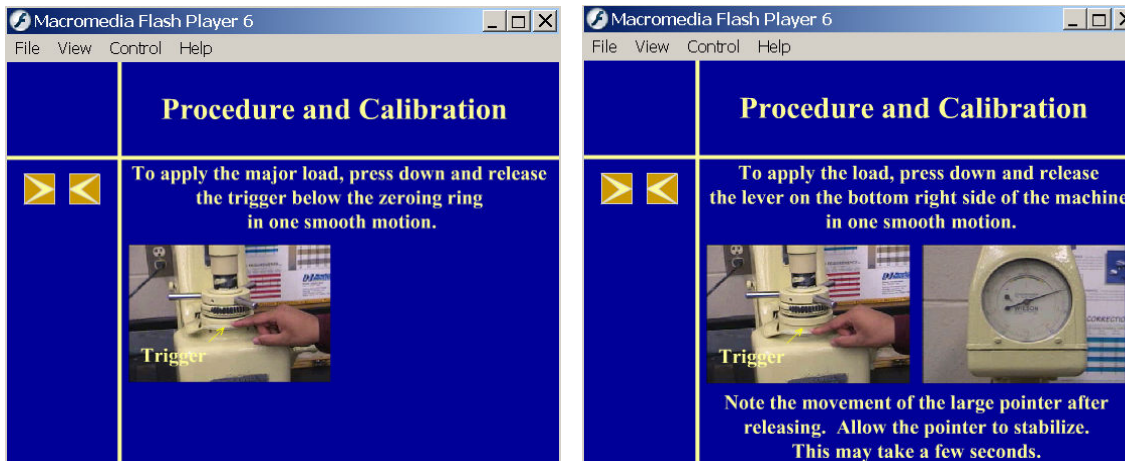
**Figure 3. Preparation of the tester for the scale of choice. (a) Indenter insertion and (b) load placement.**

Various steps are then presented through use of synchronized video clips. For example, when the ring is used to initialize the analog pointer, Figure 4a, the effect on the pointer is shown on a side by side video clip, Figure 4b. This allows the student to understand the process better.



**Figure 5. (a) Initializing analog pointer (b) Effect of initialization on the pointer**

A similar process is used to show the final steps of the process which include trigger of the load, Figure 5a and the result on the position of the pointer, Figure 5b.



**Figure 5. (a) The trigger mechanism for loading and (b) the pointer movement.**

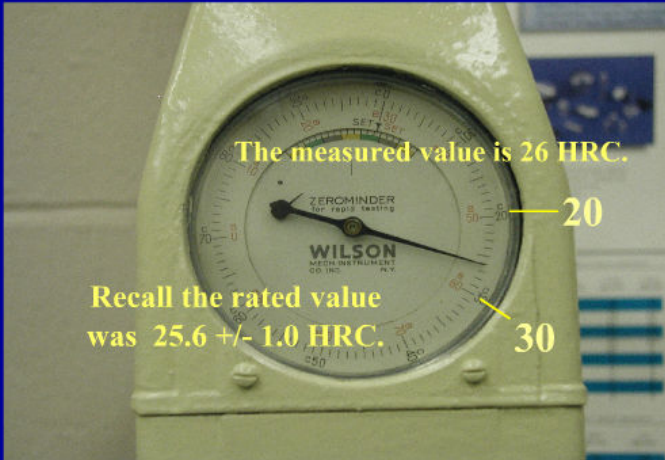
Finally, the reading of the hardness value is presented using an image that compares the dial value with the actual hardness value of the calibration block, Figure 6.

Macromedia Flash Player 6

File View Control Help

## Procedure and Calibration

You are now ready to read the value of hardness from the black scale.



The recorded value should be very close to the value marked on the C block (note the error allowance on the block).

**Figure 6. The final position of the pointer showing the measured value and its comparison with the actual value.**

The system is now calibrated and ready for use. The students will be given the ability to measure the hardness of a metal sample by selecting the proper scale, indenter, and load in an iterative manner. The actual measurement process is identical to the calibration process.

### Software Evaluation

One section of the laboratory was given the ability to view the software through the Internet. This module was placed in the department web server and students of this section were given access to the module for 10 days. There was no limit to the number of times a student could view the software. The remaining two sections were not exposed to the software. The students in all sections were given a pre-lab quiz about the objectives and important issues of the experiment. The average grade of the students in the lecture and virtual laboratory groups was approximately 20 % higher than the lecture alone groups with a p-value of 0.007 based on a t-test. The p-value of .007 indicates that the difference between the performances of the two groups is real and is not due to chance. If the calculated p-value were greater than .05 that would indicate that the difference is not statistically significant. The average grade on the knowledge of the

procedure prior to actual experiment for the lecture and software groups was 75 on a 100 basis. Also, the lecture and software students showed a great understanding of the hands-on procedure without significant input from the instructors. This allowed for a much more effective experimentation process. The lecture only groups did not have a good idea of the procedural steps and required significant guidance from the instructor.

### **Conclusion**

Interactive software is an excellent tool to prepare the students of laboratory courses for the actual experimentation period. Our results show that the students can learn the objectives and the procedure of the experiment in a more meaningful manner when exposed to such software. The software can be accessed by the student at their convenience and can be viewed as many times as the student requires.

### **Acknowledgement**

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