2006-2008: WEB-BASED DELIVERY OF LABORATORY EXPERIMENTS AND ITS EFFECTIVENESS BASED ON STUDENT LEARNING STYLE

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Web-Based Delivery of Laboratory Experiments and its Effectiveness Based on Student Learning Style

ABSTRACT

Web based preparation of students in laboratory based courses may offer unique features and benefits over conventional in-class preparation. Apart from reduced costs and training time, it is an effective tool for education and preparation of large classes, convenient for students due unlimited access without time constraints, and more importantly, it allows mistakes to be made by the users and thus facilitates learning in an active manner.

Four interactive web-based modules on Material Sciences related experiments (virtual labs) were developed at the Texas Tech University. The aim was to help undergraduate students learn more about the objectives and procedures of laboratory experiments in order to be better prepared for performing their tasks during the physical experiment.

The intention of this project was to assess the benefits of both web based training in performing the actual experiments and in the learning of students. Furthermore, we wanted to assess the perceived effectiveness of the software as a function of the student learning style and GPA performance. Access to modules was given to several sections of Materials Science Laboratory Course. A pre-lab quiz was given to all students to test the students' understanding of objectives, procedure and the anticipated results of the experiment. The learning styles of the students were determined using the on-line Index of Learning Style (ILS). The laboratory report and test scores were compared across those sections that were exposed and not exposed to the virtual laboratories. The scores were also correlated to the GPA of the students and their scores of learning style questionnaire. In all cases, the student groups that were exposed to virtual labs performed better in both laboratory quizzes and reports. The improvement in performance was statistically significant in majority of comparisons. Our research also showed all students regardless of their GPA level benefited from the virtual labs. Based on the ILS scales, our results show that active and sensing learners benefited more from the virtual labs than visual learners.

INTRODUCTION

Web based preparation of students in laboratory based courses may offer unique features and benefits over conventional in class preparation. It is generally beneficial for the students to have a more informed view of the objectives, equipment, and procedures of a laboratory experiment beforehand; however, in many situations this is not possible and students have to rely on handouts that do not provide any real insight into the actual experiment. Virtual experiments may be used as an on-line preparation tool to prepare the students using animations, video clips, interactive quizzes, and semi-open-ended structure. This not only enhances the learning objectives and in general learning but also helps them be more proactive during the actual experiment. Recently, there have been numerous efforts in adopting web-based technology for laboratory education in various fields of engineering. For example, Elsherbeni et al. [1] developed one of the early virtual laboratories in microwave and electronics as purely a visualization tool. Some of the other notable efforts are by Monter-Hernandez et al. [2] in power electronics and Avouris et al. [3] in computer-assisted laboratory courses. Some of the more interactive efforts are those reported by Bhandari and Shor [4] in the area of Controls, Budhu [5] in Soil Mechanics, Schmid [6] in Controls, and Gustavsson [7] in Electrical Circuits. 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 [8] and Experimental Methodology [9]. Others have developed on-line laboratories to introduce the equipment and the procedure of the experiment to the students before they actually participate in the physical experiment [10]. A fully interactive experiment on metallography, and a second on measurement of hardness with highly interactive decision tree structures have also been recently developed [8, 11].

It has also been argued that the impact of the virtual laboratory supplementation would be enhanced if various learning styles are considered in the design of the software. Engineering students differ in their preferences toward how they would assimilate educational materials better. These preferences can be characterized by learning style measures such as the Index of Learning Styles (ILS) developed by Felder and Silverman [1988] for engineering students and the more general Kolb [1984] learning styles. To-date, learning styles have not been linked to the perceived effectiveness of virtual laboratories or other learning resources. An objective of the present research is to look for reliable correlations between learning styles, virtual lab supplementation, and performance in the course.

Another important factor that has not been studied is the effectiveness of the virtual supplementation in relation to the student's GPA. Will the virtual modules only help the students with higher GPAs or are they equally effective with students of lower scholastic performance? In this paper, we hypothesize that;

1) Virtual experiments used in conjunction with actual laboratory experiments will significantly improve the learning performance of the students measured through quiz and laboratory report grades.
2) The virtual laboratory supplementation will enhance the student's performance regardless of learning styles.
3) All students regardless of their GPA performance will benefit from virtual supplementation.

THE VIRTUAL LABORATORY (AN EXAMPLE)

In this section, we describe the structure, content, and design of one of the tested virtual experiments on tensile testing [12]. The actual content and type of interactivity of each of the virtual labs vary according to the type of the experiment. The interactive web based tutorial is made using Macromedia Flash MX. It can be accessed either in flash player or in internet explorer. A screenshot of a general page in the tutorial is shown in Fig. 1.

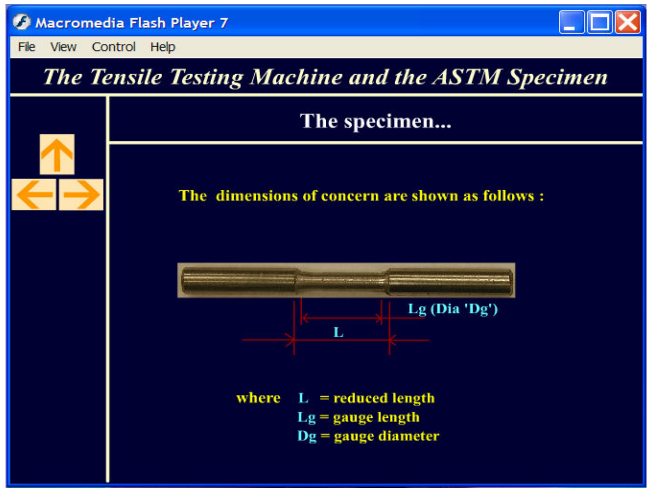

Figure 1. Layout of the software window

The web tutorial is organized into five major sections, labeled

1. Objectives
2. Introduction
3. Specimen Loading and testing procedures
4. Background of the experiment & methods to calculate various mechanical properties of the specimen.
5. Interactive decision tree structure.

The above topics are listed on the first index page (Menu). Under each topic there are multiple subtopics. One can proceed sequentially or jump from topic to another. The use has the ability to return to the main index from anywhere in the tutorial or list all available topics. , i.e. the navigation is user controlled.

The web tutorial utilizes video clips and animations to transfer knowledge quickly and to be both educational and entertaining. Each topic contains several discussion points linked to specific visual content. The strategy here is to involve different modalities of learning in order to maximize student interest, participation, and learning. Each screen is designed to be highly interactive and requires little instruction on navigation.

The Learning Objectives Of The Experiment

The learning objectives describe what the students will learn from the virtual experiment after they have completed the module. It describes the aim of the experiment and briefs about the work to be done (Fig. 2).

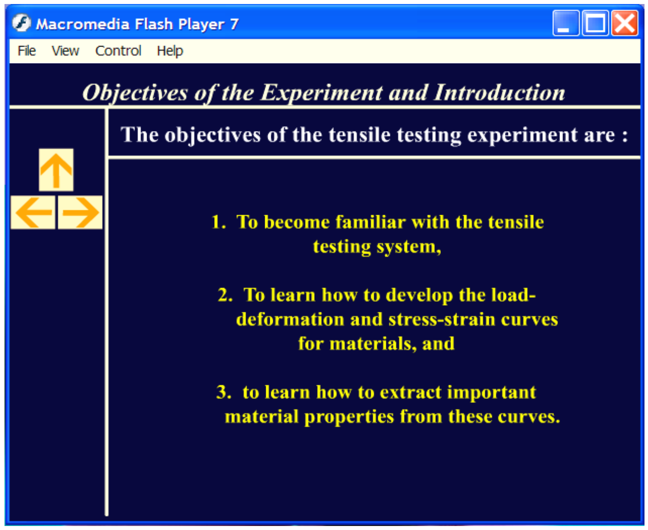

Figure 2. Screen showing experiment objective

The Introduction Module

This section introduces the students to the equipment they would be using to perform the test. This includes description of various components of the Instron Machine. By moving the mouse pointer on various components of the Instron, the description of that component pops out (Fig. 3). This module also describes what types of specimens are used for testing and various critical dimensions as per ASTM standards.

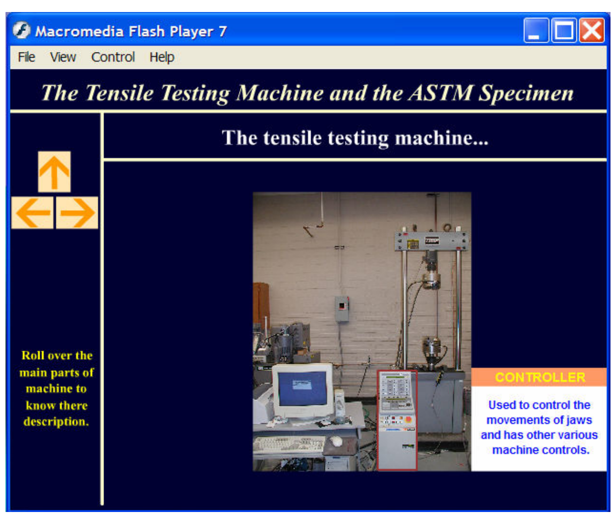

Figure 3. Description of Equipment

Specimen Loading And Testing Module

This module explains exactly how to perform the experiment. It contains video clips of how to attach the extensometer to the specimen, and how to mount the specimen on the Instron (Fig. 4) with special instructions on the grip pressures to be maintained. The testing part explains the control mechanism of the machine. It describes the load cells and explains the output data being recorded in the excel format on the computer connected to the Instron Machine. This module has sufficient video clips on the set up and the actual experiment to give a brief idea of the flow of the tensile test experiment to the student.

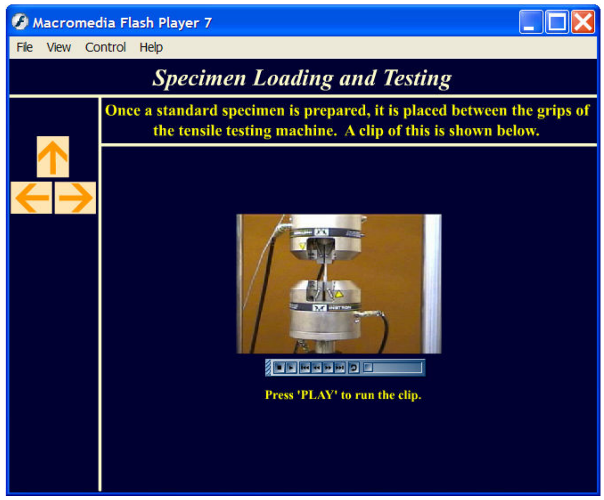

Figure 4. Testing Procedure

The Background And Theory Module

The basic theory behind the experiment is explained in this module. It explains about the concept of stress, strain, the load elongation curve, important characteristics of the stress-strain curve (Fig. 5) and describes how various mechanical properties can be determined from the stress-strain curve and how to find them.

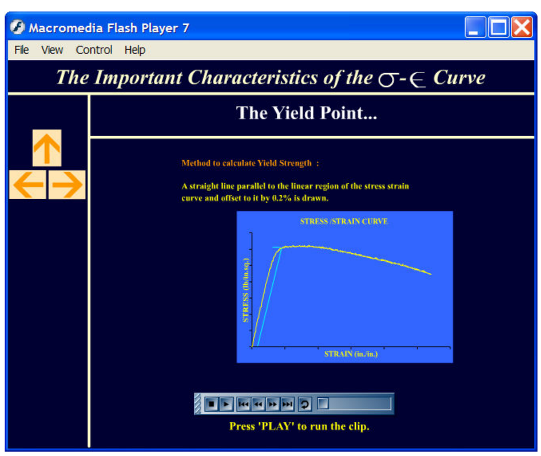

Figure 5. Explanation of the stress strain curve

Animated graphics, which are controlled by the user, are extensively used in this module. The properties that are discussed are:

a. Yield point

b. Ultimate tensile strength.

c. Fracture strength

d. Ductility.

e. Modulus of resilience and toughness.

f. Percent elongation at fracture.

This module discusses in detail each part of the stress-strain plot. It explains the importance of the plot at each stage and thus the properties of the materials very effectively with the help of flash animations.

The Decision Tree Structure

Probably, the most important part of the virtual lab is – 'the decision tree structure'. This module lets the student to determine the identity of an unknown specimen as closely as possible. They are provided various options to identify the material. They can choose hardness test, Metallography and tensile test to identify the specimen. If they choose the hardness test or Metallographical analysis as the tool of choice, they will be shown the results of those tests and will also be shown that there may be many metals with similar hardness values and indistinguishable microstructures. Thus such tools can not provide the amount of information needed to identify the metal. Next, they perform a virtual tensile test on the specimen and view the collected load-cell and extensometer detain an excel sheet. The data (load, elongation, and specimen geometry) of the tensile test is given as output in the excel sheet. The students are asked to plot the stress-strain curve of the metal, and calculate various mechanical properties of the metal using the excel sheet and enter them in the flash window again. The values can be verified then and there by clicking 'Verify values' button. These values are given 'Correct' if they fall into an admissible range to the answer (Fig. 6). Otherwise the values are given a 'Wrong' prompt and the students are asked to perform their calculations again. Once the students determine the correct values, they are provided with lists of materials that closely match the values that they have determined for each property and shortlist them. For instance, they will realize that one can find a number of compositionally different alloys that possess the same yield strength, or ductility, tensile strength. Once they examine the modulus of elasticity they realize that most alloys of the same composition (regardless of heat treatment and cold working conditions) possess the same value for modulus of elasticity. By cross comparison of metals selected based on various properties, the students will reduce the list to a final candidate.

A similar type of layout and interactivity is used in all the virtual labs. For example, in the hardness virtual lab, student is asked to find the correct Rockwell scale to measure the hardness of a Aluminum sample. The student virtually selects the scale of his/her interest and virtually performs the experiment to test the suitability of the selected scale. Similarly, in the Metallography virtual lab, the student tests virtually the effects of various etching time on the microstructure of the metal.

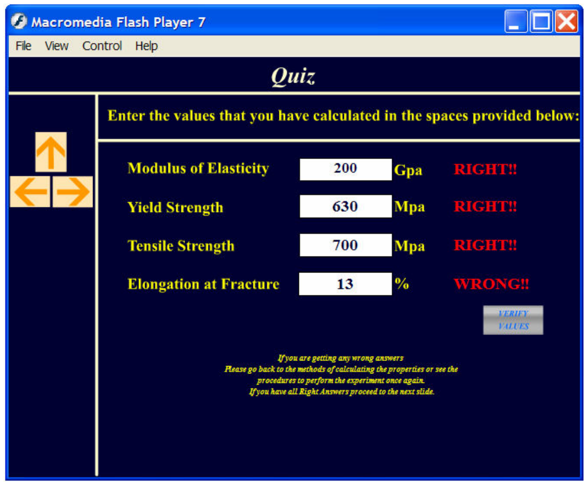

Figure 6. Verifying the calculated values

METHODOLOGY

The analysis was performed on the students of ME 3328 (Mechanics and Materials Laboratory) course at Texas Tech University on during the Fall semester of 2005. This class consisted of 64 students. While this laboratory class consists of six experiments, analysis was performed only on 4 experiments as only four virtual labs (Measurement of Hardness, Cold rolling, Metallography and tensile testing) are available at this time. At the beginning of semester, the students were asked to fill out an evaluation sheet in which they indicated their current GPA. They were also asked to complete the Index of Learning Styles Questionnaire developed by Soloman and Felder of North Carolina State University (http://www.engr.ncsu.edu/learningstyles/ilsweb.html). This survey asks a series of questions based on which a student can be identified as a) Active or reflective learner b) Sensing and Intuitive learner c) Visual and verbal learner d) sequential and global learner. The survey assigns scores which identifies the student's preference in one or the other learning method from each of the four categories mentioned above. For analysis purpose, score of the each learning style was considered as negative score of the other learning style of the same category. For example, if a student is identified as reflective learner with a score of 8, he/she was considered as an active learner with score of -8. Hence four learning style scales were developed.

Each experiment cycle consisted of an in-class lecture, a pre-lab quiz, performance of the experiment and writing a lab report. The students were divided into two groups. One group (Group A) was not given access to the virtual labs while the other group (Group B) was given access to the virtual labs which were placed in department server and password protected. The Group B students were allowed to access the virtual labs any number of times before taking the quiz and performing the experiments. The quiz and reports were graded without prior knowledge of the group the students belong to.

In order to determine the effect of virtual labs on the scores of quiz and lab reports, 2 sample t-tests were used to compare the scores for each of the four experiments. Since the academic capacity (measured by GPA) of the student might play a role in the scores of report and quiz, multivariate regression analysis was performed to compare groups A and B with the GPA of the students as covariate. In order to study the improvement in the performance of the students due to virtual environment, the average scores of quiz and reports were predicted from the GPA of the students. Then, the actual scores were compared with predicted scores to find the 'effect score'. The 'effect score' was compared between group A and B.

In order to study which is the learning style that is affected the most by the virtual environment, each of the learning style scores of group B were correlated to the 'effect score' of quiz and reports. The statistical analyses were performed using SAS and the alpha value was set to 0.05.

RESULTS

Those students who did not participate or complete the survey were excluded from the further analysis. The scores were higher for quiz in hardness (32%, p=0.001), report in hardness (3.42% p=0.02), Quiz and report in cold working (18%, p=0.017 and 3.32%, p=0.02 respectively) and for reports of Metallography and tensile testing experiments (4.6%, p=0.008 and 17.75%, p<0.001) for group B when compared to group A based on two sample t-tests. The difference in scores between group A and group B in case of quizzes of Metallography and tensile testing were 7% (p=0.07) and 3% (p=0.26) respectively with students from group B having higher scores. These differences were not statistically significant. When the analysis was repeated using ANACOVA (analysis of covariance) with the student GPA as covariate, the results remained unchanged. These results show that the virtual labs were effective in improving the performance among the students in several cases as indicated by the difference in the scores of quizzes and lab reports. The 'effect score' defined as the difference between average score for quiz and reports as predicted by the GPA and the actual score was 6% higher in case of group B for the quiz (p=0.009). For the reports, the 'effect score' was 5% higher in group B. But the difference in case of group B was not statistically significant. This shows the virtual labs help in improving the student scores independent of their GPA.

The 'effect score' for reports was positively correlated (r=0.4, p=0.03) to active learning scores. The more the student is skewed towards active learning the more he or she benefits from virtual labs. The correlation was moderate in case of sensing learning score (r=0.31, p=0.07). The correlation between learning style and effect scores in quiz and reports are given in Table 1. This shows active and sensing learners are more benefited from virtual environments than any other learning styles. It is curious though that the visual learning scores were not correlated to any of the 'effect scores'.

Table 1. Correlation coefficient between the effect score and various learning styles. The values in the parentheses are p-values.

Learning Style	Quiz Effect Score	Report Effect Score
Active	0.24 (0.13)	0.4 (0.03)

Sensitive	0.05 (0.4)	0.31 (0.07)
Visual	-0.17 (0.22)	-0.006 (0.48)
Sequential	-0.24 (0.14)	-0.28 (0.1)

CONCLUSIONS

Virtual supplementation of laboratory experiments, in an interactive manner will improve the students' performance and learning irrespective of their GPA. Active learners are found to benefit more from the learning in virtual environment.

ACKNOWLEGEMENTS

The support of Teaching, Learning, and Technology Center (TLTC) is gratefully acknowledged. Also, two of the authors (JH and EEA) gratefully acknowledge the support by the National Science Foundation's Course, Curriculum, and Laboratory Improvement Program under grant DUE-0231406.

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