Experiences With A Virtual Laboratory Class In Materials Testing  
For Civil Engineering Technology  

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Abstract

Old Dominion University has developed an extensive distance learning system that includes 32 remote community college sites, mostly in Virginia, and an additional 14 hospital, military and industrial sites in several states. Since the Civil Engineering Technology curriculum requires several laboratory courses, a problem exists for many distance learning students.

For example, one course of interest is a three-hour laboratory course in the testing of engineering materials. Some of the sites have equivalent laboratory courses that meet this need, but many are not equipped for this purpose. In the past, this class was held in the summer in a series of three two-day weekend sessions. This method requires the students to travel and stay overnight, and compresses a significant amount of study into a very short time, thereby compromising the students learning experience.

In the summer of 1998, the class was videotaped in the laboratory with all discussion, measurements and testing recorded. In the fall of 1998, the tapes were used successfully in a pilot class on campus with seven students. In the summer of 1999 a distance course was held attended by approximately 50 local and distance students. The success of this virtual approach to a laboratory class and the experience gained in the process are documented in this paper. The paper also includes a discussion of the logistics involved with a virtual laboratory class of significant size.

1. Introduction

The distance learning program at Old Dominion University features approximately 100 classes in the current semester that are presented in a synchronous or partially asynchronous format. Eight to ten additional courses are offered in a totally asynchronous format. The distance learning program has developed around the assumption that to be successful, complete programs must be offered rather than individual courses that may be selectively of interest to those in practice. One of the requirements of the Civil Engineering Technology program at Old Dominion University is a laboratory class in the testing of engineering materials. The students in the Mechanical Engineering program also take this course. The course includes basic materials experiments such as testing to determine the properties of steel, wood and concrete. Materials are tested in tension, compression and torsion. A major emphasis of the program is for the students to learn to execute experiments, anticipate the results and organize the information into a coherent report in a format acceptable for engineering practice.
Old Dominion University has agreements with Virginia community colleges to accept courses at the freshman and sophomore levels. Many of these campuses have similar courses of sufficient rigor to meet the requirements of the Old Dominion University course. Many of them do not have a course that meets the requirements. Previously, the only options for distance learning students at these locations was to travel to other institutions with the required course or attend a summer course at the Old Dominion campus. The course was held over three weekends separated by two weeks. Four classes were held on each of these weekends, with the introductory and final classes incorporated into the other 12 classes. This option requires students to travel to the Old Dominion University campus and stay overnight incurring expense and inconvenience. For some, work limitations prohibited attendance at these sessions.

Traditionally the class is held in a testing laboratory that is equipped with machines to facilitate this testing. At Old dominion University, the laboratory has four tension/compression machines, two with a capacity of 60,000 pounds, one with a capacity of 400,000 pounds and a fourth for compression testing of concrete cylinders with a capacity of 250,000 pounds. Also available are machines to test impact, torsion, fatigue and hardness.

A typical semester will include ten experiments requiring fourteen class periods of up to three hours each. The class is usually limited to 16 students, with 20 being the maximum for an on-campus class. The schedule of experiments varies with the class broken into groups of not more than four or five students for some experiments. The entire class executes other experiments as a group. A typical class schedule is as follows with classes executed by the entire class group indicated by an asterisk:

Week 1 – Introduction*

Week 2 – Verification of a testing machine. Using a dynamometer, a testing machine’s load readings are verified with adjustments for temperature. A graph indicating conformance with ASTM standards is developed.

Week 3 –Tension testing of metals. A tension test of a metal specimen is performed and material parameters determined. The parameters are compared to standard values and a stress-strain curve is drawn.

Week 4 – Hardness of metals. Using a Rockwell hardness tester, several metals are tested and corresponding values for Brinnel hardness and material yield strength are found.

Week 5 – Wood I. Specimens are testing in compression perpendicular to the grain and in bending. Parameters of the wood are obtained. Stress-strain curves are prepared and the parameters of the material are compared to standard values.

Week 6 – Wood II. Specimens are testing in compression parallel to the grain. Parameters of the wood are obtained. A stress-strain curve is prepared and the parameters of the material are compared to standard values
Week 7 – Concrete I*. Concrete mix designs are discussed and prepared. Concrete is mixed and cast into compression cylinders and a beam. The cylinders and beam are stored in a moist room for curing.

Week 8 – Impact. Charpy and Izod specimens are tested and the values for different grades of steel are compared.

Week 9 – Torsion. A steel rod is tested in torsion and properties for the specimen determined. A curve of torque as a function of angular displacement is prepared. Parameters of the material are compared to standard values.

Week 10 – Non-destructive Testing*. Metal specimens are measured and examined visually for defects. Specimens are tested for defects with magnetic particle and dye penetrant tests.

Week 11 – Concrete II*. The concrete cylinders and beam are tested and parameters for each determined. The estimated ultimate strength of each is compared to the values found by testing.

Week 12 – Fasteners. Single and double shear bolted connections are analyzed for the path of load through the connection. The connections are tested to failure and critical stress values determined.

Week 13 – Fatigue – Curves of stress verses number of cycles are prepared for smooth round, notched round and flat specimens. Values of the endurance ratio are determined.

Week 14 – Turn in last reports. Course evaluations.

2. Methods of Presentation

It has been shown that student learning is enhanced when the student has control over when and where the learning takes place\(^1\). The class was prepared as a series of videotapes, which permits students to choose the time and place to learn. Some institutions have abandoned the concept of synchronous delivery of distance learning\(^2\). This is not the case at Old Dominion University, which places a high value on faculty/student interaction, and endeavors to have at least 50 percent of all classes by synchronous. In the case of laboratories however, it is not feasible to broadcast such classes because of limitations of the screen resolution that can be produced at the remote sites.

At the time the project was conceived, alternate methods of delivery were just starting to be investigated. Other possible choices include video streaming of the class, either live or asynchronously, or streaming of a series of still images with narration. It was determined that sufficient detail could not be obtained with video streaming using the technologies currently available.

It was felt that in order for the class to be successful, it should not compromise the procedures used in the campus class. If the execution of the experiments was “staged” to a high degree the spontaneity of the class would be lost. Also, some minor adjustments in the procedure are not
unusual in the laboratory and it was not desired that such an occurrence be deleted from the videotape sections. In order to keep the distance experience as close as possible to the on-campus experience, the experiments were filmed just as they occur in the laboratory. A student assisted in the execution of the experiments, which permitted questions to be asked in the course of the filming. The student was asked to prepare to the same extent as the in-laboratory student would prepare.

The film crew transported their equipment including lights, cameras, audio equipment and producer to the laboratory. Each experiment was run in the exact manner it usually is done in class. The only interruptions were when equipment failed, or if the sequence of filming caused an unnecessary relocation of the equipment to record the experiment in the exact sequence in which it was normally executed. For instance, the hardness experiment is performed in the vicinity of the Rockwell testing machine. No work is done in another location in the laboratory. The entire experiment was performed uninterrupted in its normal sequence.

In the case of the tension experiment, the standard procedure starts at a table adjacent to a blackboard where methods are discussed and measurements made. The experiment proceeds to the universal testing machine where the test is run and data taken. Following the test, the students return to tables where they compile data and calculate parameters for the material. In the taped sequence, the taping starts at the testing machine followed by taping at the table for the first and third segments. The segments then are edited into the correct sequence. Thus, considerable time is saved in moving and setup.

The process described above is costly and time consuming. If the course is in a rapidly advancing field, such an effort may not be economically feasible. Such courses may require revision annually as compared to other, more slowly evolving areas. In the area of materials testing, the principles and methods used are not advancing at a fast rate, and we concur with previous work which expressed the opinion that this work can be useful without major revision for a period of three to five years.

3. Problems Encountered

Each of the sites in the Old Dominion University system has a site director to register students and assure that everything runs smoothly during classes, most of which are in a synchronous mode. Each site director was sent an e-mail on two occasions prior to the start of the semester with detailed instructions on how the class would be run. In addition, the class has a web page with identical instructions for students. Each student was also sent a written notification by mail that complete instructions were on the web page.

The procedure calls for the student to purchase a laboratory manual through the company that is under contract to provide texts for Old Dominion University’s distance learning program. The student obtains the tapes from the site director and after watching the tapes, prepares a laboratory report in the class standard format. The reports are submitted at the sites and forwarded to the professor’s office. Following grading, the reports are returned to the students.
Often in a new endeavor, the process does not run exactly as planned. This class was no exception. The main problem is that the students had difficulty understanding how to proceed. Although the information was readily available, students were calling long after the start of classes and asking if they needed a text. The most likely cause of this lack of information is that the students are not familiar with the asynchronous mode. Time will cure this problem, as students become more familiar with the virtual laboratory procedure. Since the asynchronous mode has not been used since that time, this question cannot be answered until the next use, which is scheduled in the summer of 2000.

Although the videotaped presentation seemed to work very well, some problems were encountered. We were concerned that the cameras would not portray the dial gages well enough to be visible. A prior investigation, which anticipated that the faculty would tape the class themselves, indicated that the equipment available at that time was not capable of focusing on a dial that was approximately one inch in diameter. The subsequent use of professional staff and equipment solved this problem. From the student’s prospective, dial reading errors occurred because of a parallax problem with the camera. Either the camera can read the dial directly, or the faculty/student can, but both views will not be accurate simultaneously. As a result, students called to comment that the readings called out did not match the readings they saw. In order to have all students’ results be similar, instruction was given to use only the data called out, which the student recorded in the lab manual forms.

Problems were also encountered with the production of tapes. The normal enrollment of 16 to 20 students was anticipated. When registration opened, over 50 students were enrolled very quickly. This necessitated closing the class with only graduating seniors being allowed in after that time. The registration process is electronic, and even though the enrollment at each site could be limited to 5 students, with the course being offered at approximately 20 sites, enrollments can become large without the instructors knowledge. Subsequently, arrangements were made to limit the overall enrollment to a maximum established number of students at all sites combined.

As a consequence of this large enrollment, the distance learning staff had to quickly produce more than twice the number of tapes that were anticipated. The set included eight individual tapes, which required the production of 240 unanticipated tapes. In order to meet this requirement, the staff tried to broadcast the tapes and have them recorded at the sites. The results were unacceptable because the taped broadcast did not produce the desired clarity for observations of specimen measurement and dial reading. Fortunately, most of the students received tapes that were duplicated on campus.

Another concern is the faculty workload. Although a large enrollment in a lecture class can be a burden, a large enrollment does not affect the faculty workload to the extent that it does for a laboratory. The primary means of evaluation is laboratory reports. One report is produced for each of ten experiments, and at a length of approximately 10 pages each, about 5000 pages had to be evaluated.
In order to assure that the videotaped course was effective, evaluation methods were considered. An essential element in this evaluation is to determine course objectives. An important element in a Technology program is the issue of "hands-on" experience. It may be inferred by the term that such experiences require that the student actually handle the specimens and run all test equipment. An assessment of what is being done in the class on campus indicates that this is not how the class is run. In order for this to happen, each student must have his own testing machine and specimens. In consideration of the cost associated with the testing equipment, it is not feasible for this class. The closest we can come is to group the students in as small a group as possible. Examining the in-lab procedures, it was found that at the most, only one of the four or five students could run the machine, leaving the others to record data or observe. In our opinion, having all students’ hands on the equipment is not feasible for this class.

It has been determined that an evaluation of the students’ reports is a meaningful way to assess the students’ performance. We concur with this opinion and feel that the essence of the class is the report produced, as it reflects the understanding that the student has of the process and serves as an indicator of the students’ ability to collect data and present it in a format acceptable for engineering practice.

Student grades for classes held in the laboratory during the period from 1994 to 1999 and for the 1998 and 1999 asynchronous sections have been tabulated as shown in Table 1. Only the data for the author is included to eliminate any differences in course perspective or grading practices by other faculty. Only students that completed the course have been included, eliminating those that withdrew. Those that completed the course but received a failing grade were included in the results. The summer sessions in 1995 and 1998 that were done over three weekends are indicated by a double asterisk.

<table>
<thead>
<tr>
<th>Semester and Year</th>
<th>Number of sections</th>
<th>Number of students (total for all sections)</th>
<th>Average grade for in-laboratory class</th>
<th>Average grade for video taped class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 1994</td>
<td>1</td>
<td>15</td>
<td>76.8</td>
<td>-</td>
</tr>
<tr>
<td>Fall 1994</td>
<td>2</td>
<td>28</td>
<td>84.6</td>
<td>-</td>
</tr>
<tr>
<td>Spring 1995</td>
<td>1</td>
<td>11</td>
<td>81.2</td>
<td>-</td>
</tr>
<tr>
<td>Summer 1995**</td>
<td>1</td>
<td>11</td>
<td>79.4</td>
<td>-</td>
</tr>
<tr>
<td>Fall 1995</td>
<td>1</td>
<td>12</td>
<td>82.8</td>
<td>-</td>
</tr>
<tr>
<td>Spring 1996</td>
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<td>7</td>
<td>82.5</td>
<td>-</td>
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<tr>
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<td>23</td>
<td>81.9</td>
<td>-</td>
</tr>
<tr>
<td>Spring 1997</td>
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<td>10</td>
<td>81.1</td>
<td>-</td>
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<tr>
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<td>22</td>
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<td>-</td>
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<td>44</td>
<td>-</td>
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</table>
As can be seen by examination of the data, the averages of the video class students equal or exceed those of the in-laboratory students. Several factors contribute to this result. Many of the distance-learning students are older and have positions in industry. Our experience indicates that students in this group often present a superior performance compared to the typical on campus student that is inexperienced. The videotape presentation itself may account for this difference. The only variation of the two methods is that the in-laboratory students must perform a preparatory assignment or complete a quiz at the start of the class. It has been our experience that if this is not done, students usually arrive at the laboratory unprepared for the experiment. Time is lost before the experiment can be started.

Obviously a preparatory assignment can not be made for the video class student. The advantage for this student is that the student can "perform" the experiment on his own schedule at the optimum time. If he is not prepared, no class time is lost. Also, and in our opinion most importantly, the student can take his time and re-rewind the tape if he does not understand what he has viewed. This gives the student the opportunity to correct errors in his data, which is something that is usually done in conjunction with his classmates in the in-laboratory environment.

5. Conclusion

The author readily admits that he was not convinced at the outset that the asynchronous laboratory would be a success. The opportunity to discuss the students’ opinions concerning the effectiveness of the laboratory has been presented on numerous occasions. The response has been overwhelmingly positive. When questioned concerning their inability to feel and hold the specimens, they in general felt that the inability to hold and feel the specimens was not a shortcoming, with the possible exception of the experiment on Non-destructive testing. In the majority of instances students obtained adequate measurements and made appropriate observations from the videotapes. Based on the response of the students that have taken this course, we anticipate the use of this and other similar videotaped laboratories in our program.

Bibliography
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