A MULTIMEDIA GEOTECHNICAL LABORATORY TEST COURSEWARE

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ABSTRACT

This paper describes a virtual consolidation test module of a suite of interactive multimedia geotechnical laboratory courseware. The module prepares students for the real test, supplements and complements the hands-on experience, extends the range and convenience of testing, test prior knowledge, guides students through the testing, allows students to prepare and interpret the test results, and allows students to apply the test results to "real" problems. Throughout the courseware, the student can monitor her/his performance and seek on-line help. The courseware has a quiz to evaluate learning outcomes and an electronic questionnaire to gather feedback from students to improve the courseware. Evaluation of the effectiveness of the courseware as a teaching tool has been very encouraging.

INTRODUCTION

Civil Engineering, like many other engineering disciplines, have several courses that require laboratory components. In geotechnical engineering (a sub-discipline of Civil Engineering), undergraduate (mostly at junior level) and graduate students conduct an assortment of soil tests to fulfill the course requirements. There is a range of problems in soil laboratory instructions. The author contacted colleagues at several institutions and some of the problems of soil laboratory instructions cited are as follows.

- Lack of testing of pre-requisite knowledge
- Students do not make the connection between theory, experiment and application.
- Some students view experiments as a chore
- Some students do not participate in the experiments
- Some students do not get hands on experience of setting up the apparatus and conducting the tests because of inadequate number of apparatuses and lack of laboratory space
- Students do not perform the whole test because of time constraints
- Equipment are out-dated and funds for replacement are inadequate or non-existent
- Some institutions at remote locations do not have laboratories
- Certain equipment, for example simple shear, true triaxial, torsional shear, etc., are absent or only found in a few research laboratories and are often not accessible to undergraduates
- Lack of teaching aid to vividly explain the intricacies of the various laboratory tests and to excite students to seriously conduct the experiments.

With the advent of computer-based technology (CBT), a large number of courses have been and are being developed for web-based instructions. It has become relatively easy to develop web-based course materials for courses that do not have laboratory components. However, technology is currently available that allows for the development of virtual laboratories. It is now possible to develop laboratory courseware that can simulate very sophisticated and costly equipment and reach a larger section of the student population. In addition, the courseware can be very valuable in enhancing learning, evaluating learning outcomes and solve most of the problems outlined above. The objective of this paper is to present a module of a CBT suite of modules developed by the author for soil laboratory instructions at the University of Arizona and students' assessment of it. The model to be discussed is called a "VIRTUAL CONSOLIDATION" module.

VIRTUAL CONSOLIDATION MODULE

Background

A consolidation test is one of the most important soil tests for geotechnical engineering. Engineers use the results from this test to calculate total and time rates of settlement, and make decisions concerning the type and size of foundation for a variety of civil engineering projects. A typical laboratory apparatus is shown in Figure 1

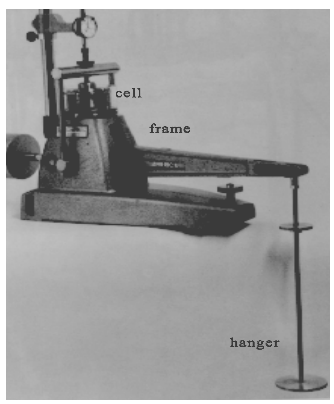

Figure 1 A typical consolidation apparatus

The apparatus consists of a loading frame and a cell. The cell comprised a ring to confine the soil sample, a reservoir to prevent drying out of the sample, porous stones for drainage of the pore water, a ring cap to hold the ring in position, and a loading cap to transmit load from the loading frame to the soil. The loading frame varies from a single cell frame to multiple cell frames. In one popular type of frame (Figure 1), the soil is loaded by attaching weights to a hanger. Hydraulic, pneumatic and other types of loading devices are now widely used in automated devices.

In a given test, several loads are applied with each load remaining on the soil for about 24 hours or more. The displacements of the soil are measured by a dial gauge and recorded by students at set intervals during each loading period. Recent designs incorporate a linear variable displacement transducer (lvdt) instead of, or in addition to, a dial gauge. The lvdt are wired into a computerized data acquisition system and readings are taken at the set intervals automatically.

In a well-organized laboratory the students do the following.

1. Prepare a sample in the consolidation ring.
2. Assemble the sample in the cell.
3. Add water to the reservoir.
4. Add a seating load, zero the dial gauge, and then add the desired load.
5. Record displacement readings at selected intervals (usually, 0.25, 1, 2.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 60 minutes, 2, 4, 6, 8, 24 hours).
6. Add twice the current load and repeat 5.
7. Continue this process (5,6) until the desired load/unloading sequence is obtained.
8. Plot various graphs to extract the relevant soil parameters, e.g., the coefficient of consolidation, compression index, pre-consolidation stress.
9. Prepare a report on the test.

A complete test may last for about two weeks. Not every student gets the opportunity to prepare the sample and assemble the apparatus. In some institutions, the sample is prepared by teaching assistants. The students are then only required to apply loads, record the displacements and interpret the results.

Module Features

Some key features of the module are as follows.

- ♦ It provides a simulated apparatus with functional gauges and other instrumentation in a virtual laboratory.
- ♦ Each student has his or her own virtual apparatus and his or her own soil sample.
- ♦ The student replicates all the steps that are required in a well-organized laboratory exercise. A student can assemble the apparatus, prepare a test sample, place the sample in the apparatus, add loads, witness the deformation of the sample, determine soil parameters from the test results and use her/his test results in a practical scenario.
- ♦ Each student is tested on (a) prior knowledge that is relevant to each test (b) learning outcomes from the laboratory exercise and (c) application of his/her results to a practical scenario.
- ♦ It provides immediate feedback, performance evaluation and help.
- ♦ It has a quiz to test retention of basic concepts.

The instructional methods and steps follow those proposed by Gagné (1985) and Clark (1989). These include: gaining attention, informing students of the objective, stimulating recall of prior knowledge, presenting the stimulus, providing learning guidance, eliciting performance, providing feedback, assessing performance, enhancing retention and transfer of learning. The flow chart in Figure 2 illustrates the key features of the module.

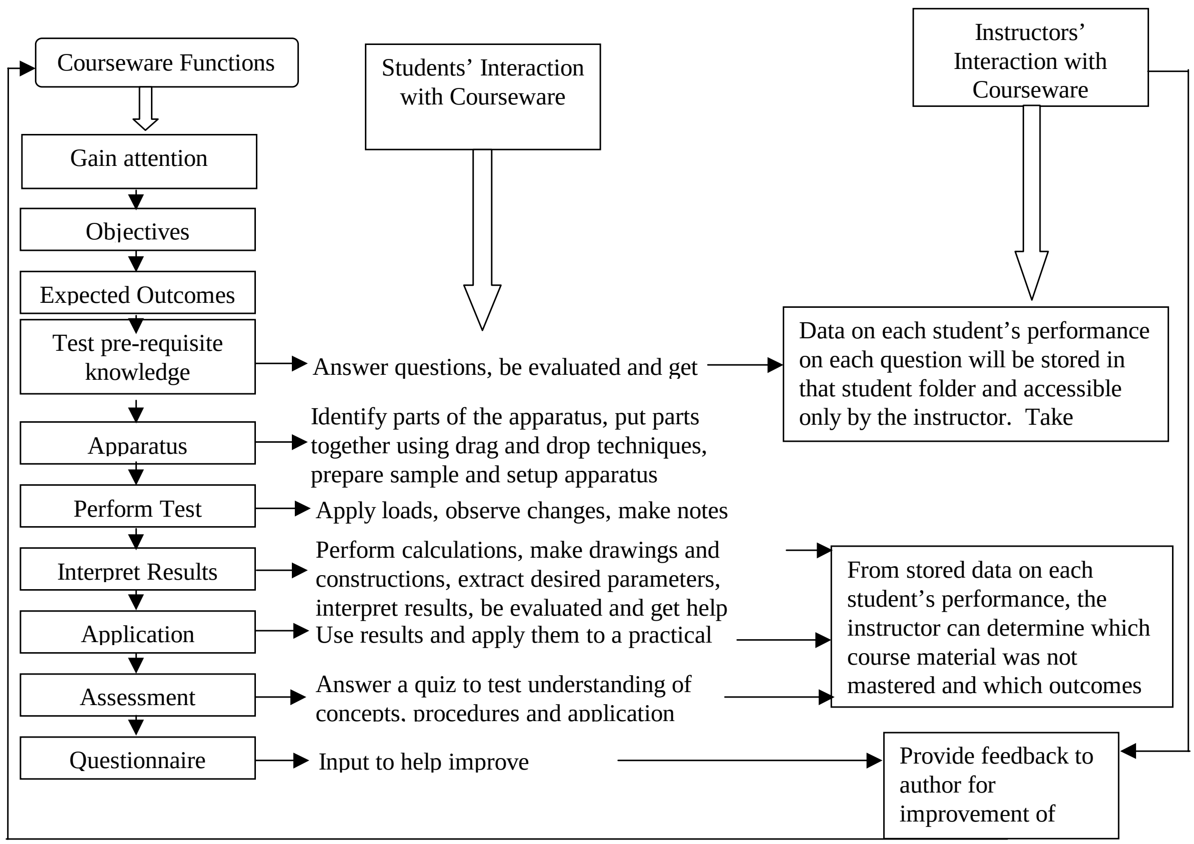

Figure 2 Flow chart of a typical module for the virtual soil laboratory courseware

Benefits of the Virtual Consolidation Test

In developing the one-dimensional consolidation CBT courseware the following expected outcomes were established:

1. enhancing retention and transfer of learning
2. supplementing and acting as a precursor for actual laboratory tests
3. better preparation of the students for the real tests
4. testing skills and knowledge that are not currently tested
5. enhancing learning about laboratory procedures, interpreting of test results and applying the results to a practical situation
6. Integrating basic theoretical concepts/principles with laboratory exercises
7. extending the range of soil testing
8. alleviating shortages of equipment, lack of equipment and inadequate space
9. enhancing the connection among theory, experiment and application
10. providing self-paced instructions
11. providing instructors with a tool to demonstrate in class the procedures of laboratory tests and interpretation of the results
12. providing feedback to the instructor on concepts that are not well understood so that remedial actions can be taken.

ILLUSTRATION OF SOME KEY FEATURES OF THE MODULE

Gaining attention: A description of the test, why the test is necessary, presentation of an image of the leaning tower of Pisa are used to gain students' attention.

Objective: The objective of the test are presented as shown in Figure 3. As the student progresses through the test, he or she is informed of the objective of the next step.

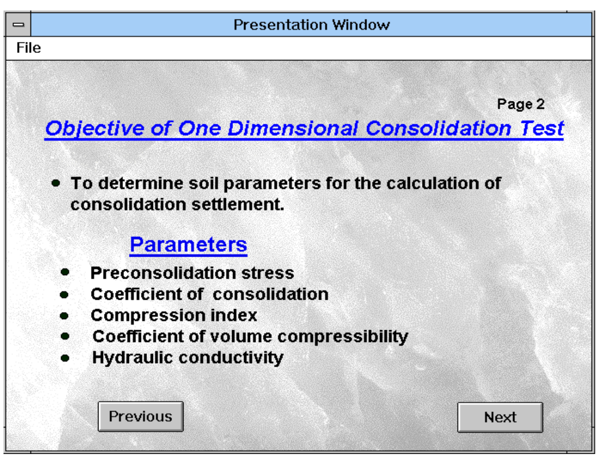

Figure 3 Screen illustrating objective

Stimulating recall of prior knowledge: The student is given a soil profile and is requested to calculate the effective vertical stress and void ratio for his or her soil sample. Realistic soil properties are randomly generated so that each student has a different set of soil profile. Figure 4 illustrates how this is done for the effective vertical stress. The objective of the interactions under this instructional method is to test the student's' mastery of the prerequisite skills before proceeding with the experiments.

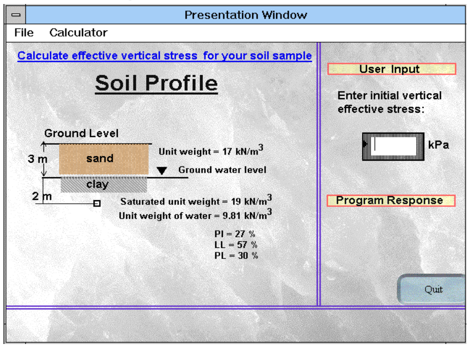

Figure 4 Screen to let a student interactively answer questions to test prior knowledge

Present the stimulus and provide the learning guidance: After identifying important parts of the apparatus, the student sets up the cell just as he/she would in a real laboratory using drag and drop interactions. Figure 5 illustrates the screen shots from the virtual consolidation module.

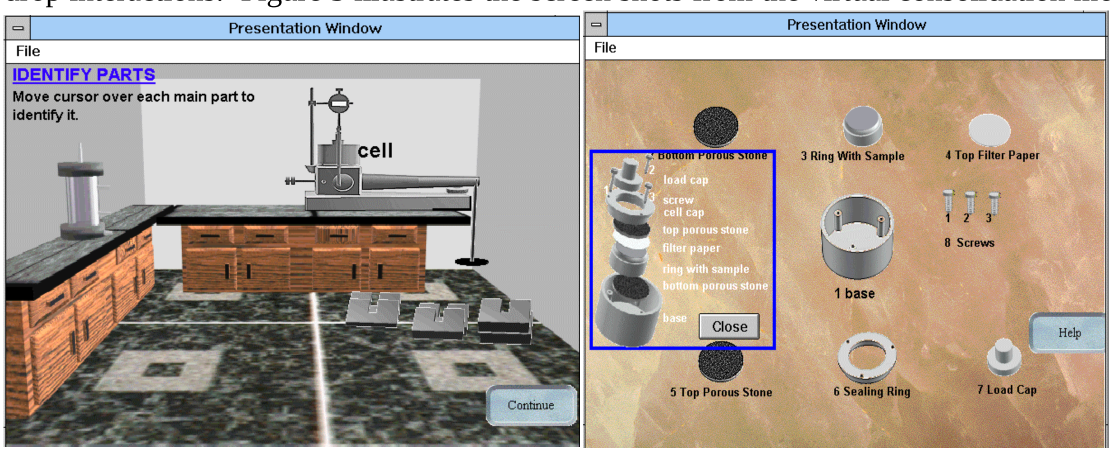

Figure 5 Screens to illustrate how a student interactively identifies various parts of the apparatus and prepare a test sample just as if he/she were to do so in a real laboratory using drag and drop interactions.

Elicit Performance and provide feedback: The internal process of responding is a critical part of the learning process. Each step a student takes in an interaction is monitored and if he or she gets a correct answer to a question, a congratulatory message appears to that effect. If he or she is wrong, he or she ise prompted to try again. Each attempt to answer the question correctly is recorded and a tally is taken at the end of the interactions. After the third attempt, the solution is presented.

Evaluate Performance: The courseware keeps track of each student's actions and points out specific areas of weakness, if any, and then guides the student to a remedial sequence. For example, Figure 6 shows a graph of the height of the student's soil sample plotted against the square root of time. The student follows a set of procedures to determine the coefficient of consolidation (C_v). The two lines shown in the figure are construction lines that the student draws.

From this graph, the student determines the time for 90% consolidation and uses this value to calculate C_v. If the student calculates C_v incorrectly, he or she is so informed and requested to repeat the incorrect segment.

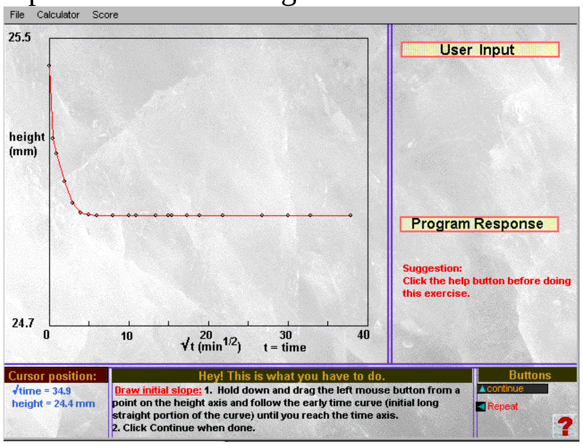

Figure 6 Screen illustrating plotted data from the virtual test

Enhance Retention and Transfer of learning: In this step, each student is given a summary of his or her results and is prompted to apply them to a practical situation. For example, Figure 7 shows the screen of the working model for settlement calculations using the results obtained from the virtual consolidation test. The student uses the calculator from the pull down menu and computes the settlement. If the settlement value is incorrect, he or she is given three tries before being directed to remedial actions. A set of interactions is developed to test each student understanding of the test and its application to real world problems.

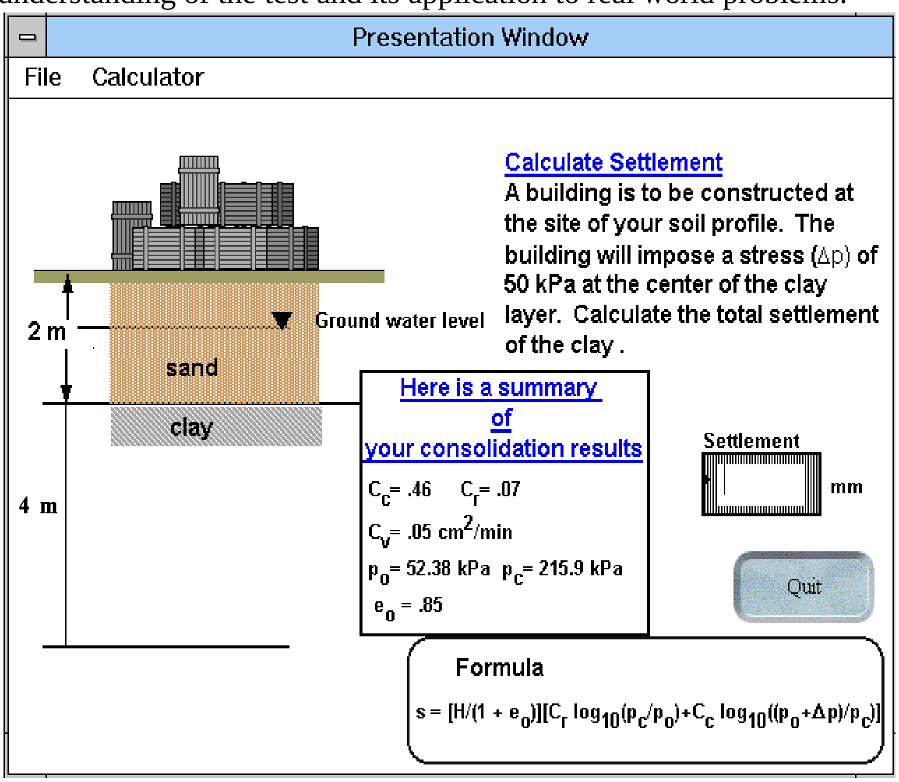

Figure 7 Screen illustrating how a student would use the results to calculate settlement of a structure founded on his/her soil.

EVALUATION

An electronic questionnaire is included in the courseware to get student's feedback. The questionnaire was geared to elicit learning outcomes. Two items from the questionnaire are:
This courseware improves my understanding of the one-dimensional consolidation test. Yes No Don't know
I am better prepared to conduct an actual one-dimensional consolidation test. Yes No Don't know

All ninety eight students at the University of Arizona, who took the geotechnical engineering course, over the last two semesters answered yes to both statements above.

CONCLUSION

The results of feedback from students and evaluation of the performances of students indicate that virtual laboratories can play a key role in enhancing learning and retention.

REFERENCES

Clark, R. C. (1989) Developing Technical Training, Buzzards Bay Press, Phoenix, AZ.
Gagné, Robert (1995) The conditions of learning, Holt, Rinehart and Wilson, NY.