Title:

An Internet-based Multi-threaded Approach to Computer-aided Learning in Civil Engineering

Authors:

Jitendra S. Sharma, Ph.D. (Cantab)
Senior Research Fellow
Institut für Geotechnik (IGT), ETH Zürich

Sarah M. Springman, Ph.D. (Cantab)
Professor
Institut für Geotechnik (IGT), ETH Zürich

Leslie R. Davison, Ph.D. (London)
Principal Lecturer
Faculty of Built Environment, UWE Bristol

Address:

Institut für Geotechnik (IGT),
ETH Hönggerberg HIL Gebäude
CH-8093 Zürich, Switzerland

E-mail:

jitendra@igt.baug.ethz.ch and springman@igt.baug.ethz.ch

Contact person:

Sarah M. Springman
Abstract
An Internet-based course has been developed for the computer-aided teaching and learning of the introductory undergraduate course in soil mechanics. The aims of this course are to improve the student’s understanding of the subject through discovery and reflection, and to support a wide range of individual learning styles. A multi-threaded approach is adopted for the delivery of this course by mixing traditional methods such as lectures, laboratory work and textbooks with interactive on-line learning resources. The course received a strong positive evaluation from the students with almost 75% finding it easy to use and extremely useful in providing basic soil mechanics knowledge and more than 80% saying they would recommend it to the students from other universities.

Keywords
Internet, On-line course, Multi-threaded learning, Java simulations, Geotechnical engineering.
Introduction

An Internet-based course has been developed at the Institute for Geotechnical Engineering (IGT) of the Swiss Federal Institute of Technology Zürich (ETHZ) for the Computer-aided Teaching and Learning for the introductory undergraduate course in soil mechanics. This course is delivered in German and forms a part of the CALICE (Computer-Aided Learning in Civil Engineering) pilot project funded by the ETH WORLD – the developing Virtual Campus at ETHZ. A parallel project is underway for the introductory structures course (CALICE – Baustatik World). The main pedagogical aims of this course are:

- to introduce the students to soil mechanics
- to improve the student’s understanding of the subject through discovery and reflection, and
- to support a wide range of individual learning styles.

These aims have been achieved most effectively by adopting a multi-threaded approach that mixes traditional methods (e.g. lectures, laboratory work and textbooks) with interactive Internet-based learning resources. These learning resources include:

- Hypertext-based on-line reference material with significant multimedia content
- Java-based simulations that promote discovery and reflection
- Challenges that include essay-type open-ended questions relating theory to practice
- Multiple-choice and numerical questions that consolidate learning and help the tutors to monitor the student’s progress.

Personalized Starting Page

The students enter the course module after submitting their user identifier and password. The first page of the module is personalized, based on the login information, and contains links to all the topics as well as the course schedule (Figure 1).

On this page, the tasks scheduled for a specific week of the course are highlighted using a system of coloured squares. A PERL script compares the current week with the week during which an assignment, e.g. a quiz or a challenge, is due. The script also checks whether the student has successfully completed this assignment or not. If the student has not completed the assignment and
assignment was due two weeks or more before the current week, a flashing red square is switched on next to the assignment, indicating that the assignment is overdue. On successful completion of the assignment, a green square is switched on next to the assignment alongside the percentage score recorded by the student. This facility encourages students to complete their assignments on time, helps them manage their time efficiently and allows them to monitor their progress.

**On-line Reference Material**

It was assumed that the students would require a script of the on-line reference material for annotation in the lectures and for reference at a later stage. An edited version of the on-line reference material, with summaries from the full script displayed in a larger text-size and with bigger images, is used for delivering frontal lectures to the students. The frontal lectures are often supplemented with video feeds (in MPEG or RM format) from the network and live experimental demonstrations.

**Java-based Simulations**

Animated simulations that cover the various basic laboratory experiments in geotechnical engineering are provided in the form of Java applets embedded in hypertext documents. These simulations are usually accompanied by one or more exercises that require the students to run the simulation in order to arrive at a solution to the problem. Some of these animations demonstrate typical laboratory tests (e.g. particle size distribution using sieve analysis, Proctor compaction test, oedometer test, direct shear test, etc.) while others simulate geotechnical processes (e.g. groundwater flow, deposition of soil particles, etc.) or provide analytical tools (e.g. Mohr circle, Boussinesq’s solution).

![Figure 2 Screen grab of a Java-based Simulation (Boussinesq’s Solution)](image)

Figure 2 shows a screen grab of an animation based on Boussinesq’s solution for stresses that are induced at any given depth in a semi-infinite elastic continuum by a uniformly loaded rectangular area. The numerical data for the exercises is randomly allocated for each student in order to discourage plagiarism. The student’s answers are checked on-line by the Java applet itself and
Challenges based on Real-life Construction Projects

Real-life geotechnical engineering projects such as the construction of an underground car park near a lakeshore (Figure 3) form the basis for the challenges. The students are given all the relevant information about the project using photographs and detailed engineering drawings. After absorbing the information, the students attempt to answer a set of three or four open-ended questions about the project. These questions are delivered using a combination of hypertext, JavaScript and PERL and do not change significantly during the entire duration of the course. In other words, the same or a slightly modified set of questions are asked at two or three different stages – in the beginning, middle and towards the end of the course. The most noteworthy and novel feature of the challenges is the facility given to the students to view their previous answers as well as the comments added by their tutors. Thus, a combination of three factors, i.e. acquiring new knowledge with the progression of the course, an opportunity to reflect on previous answers and the benefit of constructive feedback from tutors, makes the challenges a progressive learning and a confidence building experience for the students.

Multiple-choice and Numerical Questions

In order to satisfy the two different pedagogic requirements of providing instant feedback to the students and monitoring their progress, twin delivery mechanisms were adopted for the multiple-choice and numerical questions. First, a master file that contains all the multiple-choice and numerical questions for a topic was created. This text file was then used in combination with a customized PERL script to generate hypertext documents containing all the questions but without dynamic allocation of numerical data (Figure 4). These are termed Practice Questions and provide instant feedback in terms of marks out of 10. If a student gets the answer right at the first attempt, he/she gets 10 marks. If he/she gets it right at the second attempt, he/she gets 6 marks. On getting the answer right at the third attempt, he/she gets 4 points and so on. After finishing all the practice questions, the student can read his/her percentage score in a text box provided on the left. The students are encouraged to test their knowledge using the practice questions before attempting the assessment quizzes. There are typically two to six quizzes per topic. These quizzes are delivered using PERL scripts and incorporate random question selection from the master file, random ordering of the questions within a quiz and random allocation of data for the numerical questions (Figure 5(a)). Hence the probability of two students getting the same set of questions or same data
in the quizzes and discourages plagiarism. Additionally, the marking procedure includes a full mark for a correct answer, no mark for admitting that they didn’t know or an incorrect numerical answer and minus half a mark for a wrong answer to the multiple choice section. Figure 5(b) shows a typical response generated by the scripts after submitting the answers.

![Figure 4](image1.png)

Figure 4 Screen grab of practice questions showing a wrong and a right answer

![Figure 5](image2.png)

Figure 5 (a) Screen grab of a dynamic quiz delivered using PERL script (b) Response generated by the script after submission of answers

**Quality Control**

The team involved in the development of the course material included up to 10 individuals. Some people worked almost full time on the project whereas usually at least two teaching/research assistants were called in on a regular basis to check each section for appropriate grammar and translation (where necessary) as well as technical functionality and accuracy and to comment on the consistency and content. A final quality controller read through the penultimate versions prior to publishing on-line. While not absolutely every error was spotted before publication, this procedure eliminated the very great majority. The flexibility of this mode of information distribution allowed
Laboratory experiments
An additional feature of the course was the inclusion of 3 experiments, which were carefully designed to add the sensory aspect to the student’s appreciation of soil behaviour. The style was deliberately planned to encourage the students to interact with each other and their supervisor, in carrying out a series of tasks and by exploring the reasons for the soil response by answering a series of questions. Normally, one supervisor was assigned for six students, working in two groups of three students each.

Students’ Performance and Reactions
On 8 February 2001, the introductory course in geotechnical engineering concluded successfully. A quick look at the performance of all the students revealed that almost 95% of the students had completed all their assignments successfully. Most students managed to score between 60 to 100% marks in the quizzes. During the course, the students were asked to fill in two on-line evaluation forms – one before the Christmas break and one after the end of the course. The evaluation forms used the Lichter scale (Strongly disagree to Strongly agree on a scale of 1 to 5) for most of the questions and included textboxes for submitting specific comments or concerns. Some of the questions asked were:

- How would you rate the progressive learning experience provided by the challenges?
- Was the course successful in providing you with basic geotechnical engineering knowledge?
- On average how many hours per week did you spend on doing various assignments?
- Would you recommend this course to the students of geotechnical engineering from other universities?

In order to gain an insight into their perception of the changing Internet technology, the following questions were also included in the first evaluation form:

- Do you have a laptop with Internet access or intend to have one in near future?
- Would you like to view and listen to the lectures on the Internet (live webcast)?
- Would you be interested in making use of the wireless LAN that was recently installed at ETH?

The on-line course module received a strong positive evaluation from the students. Almost 75 % of the students found it easy to use and extremely useful in providing basic geotechnical engineering knowledge. More than 80% students said they would have no hesitation in recommending it to the students from other universities. It was revealed that the students were able to complete all their assignments for a particular week in less than 3 hours per week. This compares rather favourably with the planned computer-based study time of between 2.5 and 3.5 hours per week. Most students responded to the technology-related questions in a fairly conservative manner. There was a strong opinion against the use of live webcast of lectures, which might be offered in future versions of the course. Most students said they would rather come to the lecture theatre in person than watch/listen to a webcast or read the notes from a computer screen. This was born out by the student attendance, which was estimated informally to have been regularly about 80% of total numbers registered (this was surprising in view of the easy availability of the course material). A significant number of students owned a laptop already, but those who did not were undecided about buying one in near future. The continuation of the laboratory experiments was strongly supported, in that the students felt that the timing and content was appropriate and that this helped them to understand the soil behaviour better.
Conclusions
On-line teaching and learning modules for the introductory geotechnical engineering course has been implemented successfully at the Institute of Geotechnical Engineering, ETH Zürich. This is the first time that Internet-based teaching tools have been used at ETHZ for delivering a geotechnical engineering course. The evaluations and comments from the students were extremely positive. This course material will be improved and refined, and an enhanced version will be used for the same course in the academic year 2001-2002.

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