Virtual soil laboratory: an exemplar of e-learning in construction

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ABSTRACT | Web-based teaching and learning have become increasingly popular, both for institutional and personal lifelong learning. Learning through the web enables students to structure their pace of study. In addition, the demand on resources such as educators' time and space can be reduced. The objective of the paper is to describe learning theory and how people learn through a constructivist approach. The paper also describes the development of a web-based virtual soil laboratory and its realization, followed by highlighting the benefits of the system. It is concluded that the virtual laboratory is a supportive teaching aid and students have benefit from "learn how to learn" through constructivist approach of learning.

KEYWORDS | virtual soil laboratory, constructivist approach, simulation, web-based teaching and learning.

1 Introduction

The concept of teaching and learning in a virtual environment is relatively new to most participants in the educational system. Virtual education has been identified as a new discipline by Khan [1]. Tiffin and Lalita [2] viewed the virtual learning as a major part of social change in the Information Age. There are many terms in relation to virtual education such as "virtual learning", "virtual instruction" [3], "virtual university" [4]. Generally mean to move courses into a new learning environment as the "virtual classes" or "virtual learning spaces" [2]. Hiltz [5] coined the term "virtual classroom" as "a teaching and learning environment located within a computer-mediated communication system which is constructed in software". The effects of virtual classroom learning are arguable. The major advantage of virtual education is that students can access the same lessons, learning materials and resources through technology at any place and any time [6]. The virtual instruction is more focused on the constructivist approach of learning [7] which suggests that learners build a knowledge base through personal experience. This contrasts with the objectivist approach of learning [8] which states that the role of educator is to transfer knowledge to a student. Even though the "educational technology"[6] have been concerned with a less holistic experience in real life, grounded in real communities [9] and reducing the ability of collective action to improve the quality of education for all [10]. Local "school" no longer has a monopoly on the provision of education as formal learning is becoming increasingly independent of time, location, or both [6].

The use of computers in engineering education is not

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new. A significant shift in technology implementations that is apparent in engineering education today is toward greater use of computers and other devices as tools in the learning process rather than instructional delivery devices. To take the advantages of new technology, a virtual soil laboratory has been brought into the World Wide Web. The web-based virtual laboratory aims to help learners become critical thinkers who can assess information and who continue to learn throughout their lives. In the field of civil and geotechnical engineering students conduct a variety of soil tests to fulfill undergraduate soil mechanics courses requirement. There is a range of problems in soil laboratory instruction, such as, some students not getting hands on experience of conducting tests because of inadequate number of apparatus, time constraints and inability in exciting students to seriously conduct the experiments. However when these laboratory soil tests are simulated with multimedia interaction and visualization techniques, the student's conceptual understanding of soil mechanics is enhanced.

The purpose of this paper describes learning theory and how people learn through a constructivist approach. The development of virtual soil laboratory is illustrated by an example. The virtual soil laboratory is considered to be an exemplar of E-learning in Construction and a Web-based educational tool being developed mainly to support students of Building and Construction department at the City University of Hong Kong.

2 E-learning: the constructivist approach

Gagne [11] describes that educational and instructional design has gone through three phases. The first phase is in modeling instructional design which was based upon behaviorist psychology; followed by cognitive psychology as phase two and the conditions of learning being the third. These theories focus on the goals of education and how to achieve those goals. The current focuses are on constructivism, which is a philosophy of learning that knowledge is constructed by learners based on their mental and social activity [12]. Educational technology may be making important moves toward constructivism [3]. The constructivist environment is becoming more and more of a reality for learning experiences that take place at a distance. In order to learn, learning needs to be situated in problem solving in real-life contexts [7] where the environment is rich in information with not right answer and learners are active in seeking meaning [12]. A constructivist perspective is a necessary component of the educational experiences that will lead students to a meaningful use of the vast amount of information that is now available to them through technologies, including the virtual environment [3].

Constructivist virtual educational experiences imply a decentralized and flexible model [6]. Learner responsibility becomes more important in virtual educational situations because there are fewer constraints on the time and place [13]. Duchastel [14] develops a web-based student-centered model for university instruction. His teaching model is "to specify goals to pursue, to accept diversity of outcomes, to request production of knowledge, to evaluate at the desk level, to build learning teams and to encourage global communities". Therefore, student motivation for learning [15] is an important factor for success. Ritchie and Hoffman [16] provide guidelines on strategies and tactics for motivating learners such as identifying learning goals, linking new information to related knowledge, requiring active involvement, providing feedback, testing, and providing enrichment and remediation. Kirschner [12] suggests collaboration learning and co-operative learning. Collaboration is a philosophy of interaction and personal lifestyle while co-operation is a structure of interaction designed to facilitate the accomplishment of an end product or goal through people working together in groups [17]. Research indicates that interactive, self-directed learning and higher order thinking can be fostered by technology [3]. This suggests the virtual laboratory be designed to create a learning environment towards the constructivist approach of teaching and learning.

3 The web-based virtual soil laboratory

The web-based virtual soil laboratory has been developed in a similar approach as the virtual class and towards the creation of constructivism environment for teaching and learning. Virtual instruction is more than a way to reach the students who are previously inaccessible because of their remote geographical location [18]. The activities of the learners are the main determinant of learning outcomes [19]. The virtual lab focuses on the soil experiments that are required for all geotechnical engineering students.

All Civil, Building and Construction engineering students pursuing a bachelor degree are required to take a fundamental course in Soil Mechanics and Foundation Engineering. In this course, the students are taught how to categorize the soil into different groupings such as gravel, sand, silt and clay, and evaluate the properties this soil will possess. Students are required to familiar with the most often used experimental tools in geotechnical engineering, and to establish an understanding of the role and benefits of experimental work for their future professional practice. Colleges and universities who offer geotechnical programs face the problems of less laboratory space, limited equipment and time which allow each student to participate actively in all laboratory exercises. Few laboratories have enough space to accommodate the equipment and enough time to permit such a long test. This experiment is thus usually limited to a single load increment, with readings taken only for the duration of a regular laboratory class. Consequently, many students do not obtain full benefits from hands-on exercises. Incomplete testing, poor quality of the results obtained, multiple sessions and large testing groups, with limited individual participation, may all result in a low level of understanding of the subject. A possible conservative solution to this problem, purchasing more equipment and hiring additional laboratory personnel, is likely not the one sought of fiscal restraint.

The development of a virtual teaching environment of a computer based instructional package – A web-based virtual soil laboratory is a more radical solution. It is intended to complement, and potentially replace, some physical tests in a real laboratory with computer-aided instruction in the form of self-contained interactive software. It is also anticipated that this will enable improved and enriched individualized learning, partially free of time limitations, which will be more productive for the instructors and more efficient and appealing to the students. Students will benefit from “learn how to learn” through constructivist approach of learning.

4 The learning concept of virtual lab

Martinez [20] studies individual learning differences and emphasis on how the differences influence successful online learning. He suggests developing sophisticated audience analysis, assessment, and learning performance models that integrate the comprehensive set of conative, affective, cognitive, and social aspects of learning. Empirical analysis from Beishuzen [21] finds there are different learning styles, namely, deep learning and surface leaning styles. Deep learning students more often used a concept map as an orientation and starting point for further explorations. Surface learning students did not utilize this facility and followed text relations connecting one text page to another in search of the quested information. A “Computer Assisted Study Environment” is a tool for diagnosing study problems.

The traditional learning process (Figure 1) for geotechnical students is to attend lecture to study the relevant theory. Then laboratory sections put theory to practice. As lack of resource and time limitation, some students have actually no chance in experiencing the real testing.

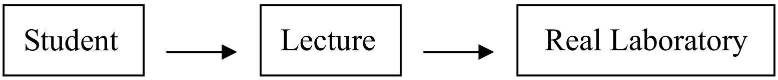

Figure 1. Traditional Process of Learning

Learning has been defined as the process whereby an organism changes its behavior as a result of experience [22]. Learning is seen as an active mental process, typically, is the ability to remember, understand, and apply knowledge and tendency to have certain attitudes and values. There may be three phases of learning. The first phase is acquisition. Students receive information and know what the things were then to remember, acquisition of new meanings from presented learning material [23]. At the second phase, retention, students possess logical meaning and have long-term memory on what they have learned. In the third phase, students can anchor ideas in related to new material and development of creative thinking to solve problem. Ausubel [23] emphases that meaningful reception learning and retention are important in education because the human being have large capacity to acquiring and storing the vast quantity of ideas and information. Gage & Berliner [22] discuss the cognitive ability as the rightness, sharpness, the ability of understand things, solve problems, figure things out quickly, and learn from experience. Among the elements, the ability to deal with abstractions, the ability to solve problems and the ability to learn are the three elements agreed by a group of experts in psychology and education. The virtual class can then provide such learning environment to suit students learning activities.

The virtual web-based soil laboratory is therefore developed in accordance with the alone concepts of learning theory. It is designed to improve the traditional learning process. Students learn through the subject both in the lecture and the virtual lab. Students can also pre-study through virtual lab before the lecture or review and practice in the virtual lab after the lecture. Students can repeat the experiments using virtual lab in the web if there is not chance experiencing in the real lab.

5 The virtual lab design

Oliver [24] concludes that the learning achieved through use of the web depends not only on the quality of the learning materials but also on the ways they are used by the learners and are implemented by the instructors. Organization, orientation, navigation, presentation and interactivity can support the effectiveness of a course and facilitate learning. The virtual soil laboratory is designed as an IT-based teaching and learning system which focus with three learning – specific components i.e., the communication component, the data management, and the learning-specific functions [25].

The virtual soil laboratory is designed to encompass most of the topics studied in civil, building and construction courses, and to serve as a synchronous tutorial tool. It can be used by the instructors to enhance their lecture presentations and by individual students to improve their understanding of concepts in soil laboratory testing and their ability to analyze various rigid and elastic structural systems. Therefore, the design for the virtual soil laboratory considers not only to meet the learning theory but also to provide constructivism environment of learning; not only to meet the technology requirements but also to provide user-friendly tools.

The design of the virtual soil laboratory follows the established processes in instructional design as shown in Table 1. The program must be available both inthe laboratory computers and at home, to relax the time constraints on students. However,

Table 1. Design Process of Virtual Geotechnical Laboratory

Stages	Topics	Tasks
Needs Analysis	Learning context	Learning environment
		Access to the learning system
	Learners	Prior learning / experience
		Attitudes and goals
	Learning task	Learning goals
		Assessment of achievements
Development	Organization	Content analysis
		Instructional strategies
	Delivery	Types of media
	Management	Working team
Evaluation	Formative	Testers
		Questionnaire
		Revisions
	Summative	Testers
		Questionnaire
		Content update

Table 2. Description of Simulation

Simulation Number	Title/Description
1	Determination of Particle Density (Density Bottle Method)
2	Determination of Particle Size Distribution – Wet Sieving Method
3	Determination of Particle Size Distribution – Pipette Method
4	Determination of Atterberg Limits – Liquid Limit
5	Determination of Atterberg Limits – Plastic Limit
6	Determination of Dry Density / Moisture Content Relationship
7	Determination of the Permeability – Constant-Head Test
8	Determination of the Permeability – Falling-Head Test
9	Consolidation Test (Oedometer)
10	Direct Shear Test

the simulation program and video tips in the virtual laboratory are mainly for the high-speed Internet connection based. To overcome this potential problem, CD (compact disc) for laboratory manual and simulation program are prepared so that the users can join the virtual soil laboratory without any Internet connection.

The ten tests that were chosen for the virtual soil laboratory are described in Table 2. These cover a wide range of tests on soil behavior. They are intended to examine, the apparatus used in experiments, the procedures, data analyses prescribed, etc. They differ in the entire visual aspect visual aspect of their description, simulation and presentation. The choice of simulation programming environment (software tools) was directed by the following considerations:

- Hardware platforms
- Multimedia capabilities (to easily accommodate various types of content: text, pictures, animations, video, audio, etc.)
- Software compatibility (for data exchange with various auxiliary programs which may be used for preparation of the multimedia material for the courseware)
- The development platform's longevity (because of the future maintenance of the product), and the programming skill set needed.

Students can have enough knowledge on the soil laboratory test through the virtual soil laboratory website, after then students joint the soil laboratory with a group. Usually one group consists of four or five students. Before doing the tests during soil laboratory class, an experienced technician will demonstrate the performance of testing and lecture will be joined to aid in the mentoring, instruction, tutoring and assessment of students. The expert performance will be a system to monitor weak or irregular performance by the students and give feedback to the students and reports to the faculty.

6 The development of the virtual soil lab

The objectives of developing the virtual laboratory are to provide students with an online tutorial tool that would

- Help enhance their knowledge and understanding of soil laboratory testing;
- Present the important concepts in a manner that is easy to comprehend;
- Provide example problems that can be altered to answer "what if" questions;
- Answer their frequently asked questions;
- Provide them with interactive exercises to improve their problem solving skills;
- Offer them the opportunity to post questions to a specific instructor.

Provide instructors with a tool that would

- Help make their lecture presentation more effective;
- Enable them to experiment with an alternate method of teaching;
- Reduce the lecture time devoted to mundane aspects of the course;
- Facilitate teaching students with different learning styles.
- A website for virtual soil laboratory has been developed (bcpc06.cityu.edu.hk/~soillab). The contents of the virtual laboratory therefore include with Lab News, Lab Staff, Research, Experiments, Simulations, Guest Book, FAQ and so on to achieve the objectives. In each experiment, the educational materials consist of procedure manual, self-assessment quizzes and simulation. Apparatuses and each step of procedures are synchronous with videos.

7 Illustration

Figure 2 shows a video file of the laboratory testing as a tool for web-based teaching technology. The expert technician who has more than 10 years experiences did the test following the procedure on the manual. The user looks over the test procedure through the video file repeatedly. This will be a very useful tool so that the student can perform the laboratory class with thorough preparation. To provide high-quality learning content, methods and techniques of computer graphics have to be embedded. Multimedia learning content, i.e., the combination of text, graphics, audio, video, the use of virtual reality and simulations, and numerical data, addresses the human cognitive capacities and conveys knowledge in a vivid and realistic way and need to be communicated in a timely manner. Students therefore can take the advantage of computer knowledge to recognize required experiments for their courses and get first impression before their real experiment in the laboratory.

Self-assessment quizzes were also imbedded to strengthen the main theoretical concepts, testing

Figure 2. Screen of Video File on the Sieve Analysis

the user's understanding of basic definitions and terminology, and to examine their applicability through simple problems. The important feature of the learning process is the verification of the learning success. The learner has to answer test questions and the test results are collected. An example of such a question is shown in Figure 3.

Feedback is critical to effective learning and includes basic theoretical explanations that describe the phenomenon mentioned in the question. In any case, to prevent potential cheating when the program is used for marking purposes, the questions are programmed mostly as simple procedures with variable, randomly chosen input. For example, in multiple-choice questions the order of proposed answers is constantly changing with each new run of the quiz. In the case of numeric calculations, the answer is computed during the run-time, depending on the random input within a priori determined limits. User interaction is mostly reserved for the simulation and the quizzes. It was assumed that the user would have significant prior knowledge of the subject (being taught that in the classroom). Thus, the main goal of this section is not to teach new content, but to provide an opportunity for review and remediation. Figure 4 illustrates an example of the feedback generated from self assessment quizzes on particle size distribution. Another aspect of the educational materials will be expert system that will monitor the use of the web-based laboratory system. This system will monitor the performance of the users of the system and give suggestions and feedback to the users (students) and give reports to the faculty members. More development of this area is in progress.

Simulating cognitive activity during learning usually improves the effectiveness of learning. The simulation program for website teaching is a computer based instructional package which is intended to complement, and potentially replace, some physical testing in a real soil laboratory. It is intended to develop an experimental simulation program toward active learning and

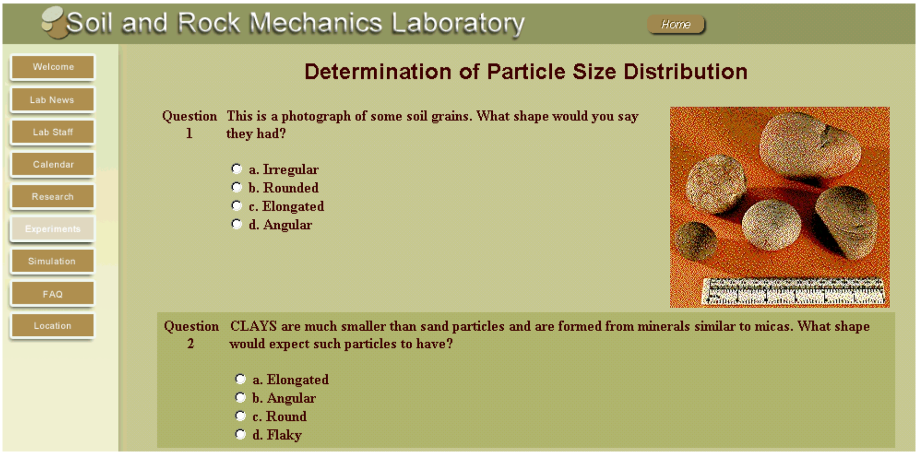

Figure 3. Example of Self-Assessment Quizzes on Particle Size Distribution

Question	Your Answer	Correct Answer	
1	Irregular	Rounded	wrong
2	Flaky	Flaky	correct
3	2.0 mm to 60 mm	0.06 mm to 2.0 mm	wrong
4	CLAYS	CLAYS	correct
5	a uniformly graded	a uniformly graded	correct
6	a gap-graded soil	a gap-graded soil	correct
7	D_{30}	D_{10}	wrong
8	The particle size for which 30% of particles are finer and 70% are coarser	The particle size for which 10% of particles are finer and 90% are coarser	wrong
9	3.3	5.3	wrong
10	1.18	1.18	correct
			You got 50% correct.

Figure 4. Results of Self-Assessment Quizzes on Particle Size Distribution

development of critical thinking skills, including data interpretation, understanding of the processes and influential factors, and problem solving. It enables students to access web site to learn experimental procedure at any time or place. The principal objective of the Java simulation based lab test module is to provide students with the opportunity to carry out soil test on-screen using an interactive virtual instrument set-ups, and step-by-step test procedures. This allows instructors to modify the different test simulation, to reflect their own requirements for technical contents and learning styles. Screen design is an issue of great important for multimedia projects. It has a crucial role in the delivery of information to the learner. In this case, regardless of the diversity of the content, a uniform and consistent screen layout is adopted to provide effective instructions, appropriate navigational tools and visual aesthetics. The simulation graphics screen for sieve analysis and constant-head permeability test is shown in Figure 5 and 6, which consists of four panels.

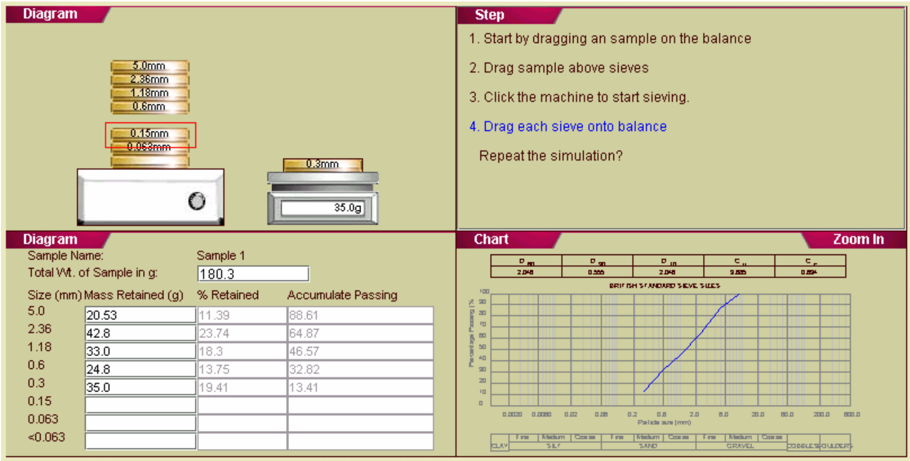

Figure 5. Simulation Screen of Sieve Analysis

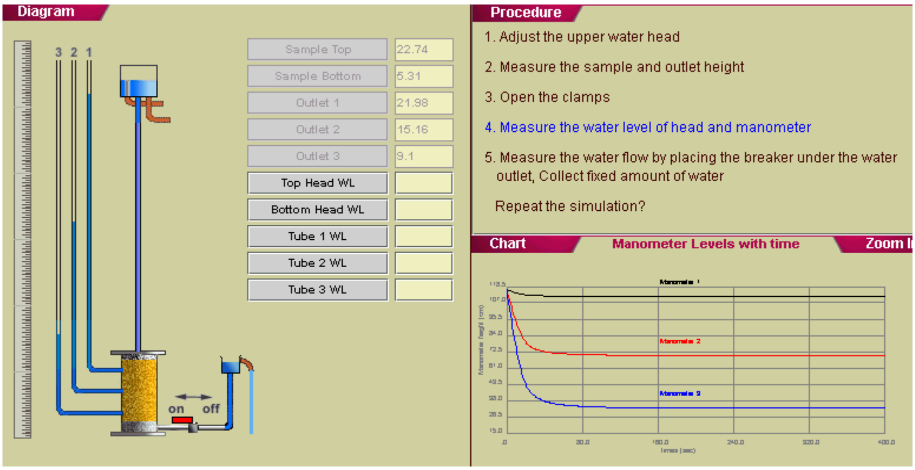

Figure 6. Simulation Screen of Constant-Head Permeability Test

The simulation programs are linked to the soil laboratory website. The main screen of the guided tutor module consists of the following:

- Diagram – The panel consist of animations and apparatus. You can see the animation of soil testing.
- Procedure – For running the simulation program, the users can choose on experimental instruction by follow any one of the steps in the procedure panel and the procedure will be illustrated automatically. Some unimportant steps are skipped for the brevity of simulation program.
- Data sheet – Data sheets have two options, one just follows the input data for the simulation work, and the other option is user-input data. In the user input option, the user uses their own data obtained form the real laboratory tests and observed the test results through the chart.
- Chart – The users can see the test results at the chart at the same time with simulation. The chart can be

expended a clearer view by zooming in and returning back original chart, using the zooming out function.

To know the feedback of the virtual lab, "Guest Book" is a place provided for the user to comment their opinions. One of the web visitors has provided his comment, "I am impressed with your mission for an online laboratory. I am a young geotechnical engineer with little experience in laboratory testing and analysis. I viewed your website and am very interested". To test the effectiveness of the teaching and learning through virtual lab, Random interviews had been conducted with students who have taken the courses. Positive feedbacks were received from students who found preparation for laboratory session easier. In addition, reviews can be done in a more interesting way.

8 Conclusion and discussion

Based on the results of this study, it is concluded that innovative use of computer simulation in traditional lecture-lab activities such as soil mechanics as presented in this paper enhances the performance of the students. Guided computer simulation activities can be used as an educational alternative to motivate students into self-discovery and to develop their reasoning skills. The lab activity can then focus on the actual transfer of knowledge. This strategy helps improving the effectiveness and efficiency of the teaching-learning process.

In situations where the objective of instruction is to learn the facts without application or transfer, method of instruction is not a significant factor. However, if the educational goal is for students to transfer and apply the knowledge to real-world problems, then simulation integration into the class structure is an effective learning strategy. One of the true benefits of the proposed courseware model is its flexibility of usage. The feedback from students has been positive in that they see it as being a useful self-learning mechanism. Although the presented approach is being applied to soil testing laboratory, it employs a generic architecture, which is discipline independent and can be adapted to any other similar domain. A virtual soil laboratory provides a constructivism of learning environment. It allows individuals who can engage in critical thinking and knowledge-creation activity, assess and evaluate information for them and work collaboratively. It is one of the innovative approaches for the enhancement of teaching and learning.

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