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Use of Interactive Classroom Models and Activities to Increase Comprehension of Geotechnical Engineering Concepts

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Use of Interactive Classroom Models and Activities to Increase Comprehension of Geotechnical Engineering Concepts

Most civil engineering programs require an introductory geotechnical engineering course that has a required laboratory component. Geotechnical Engineering involves fundamental concepts associated with soil mechanics, which are difficult for undergraduates to grasp using conventional lecture methods. While engineering students are capable of ‘utilizing’ equations to solve geotechnical problems, they have a difficult time ‘comprehending’ the equations, fundamental concepts, and the engineering application. The ability to reach higher levels of comprehension is contingent on mastery of the foundation material. It is important that faculty use diverse teaching methods and encourage students to elevate their level of thinking. One way of doing this is to facilitate interactive classroom experiences and learning.

As part of a four semester long course curriculum improvement research grant funded by the National Science Foundation Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics (TUES) Program, the use of interactive classroom tools referred to as Geotechnical Concept Tools (GCT) have been developed and are in the process of being evaluated. This project involves a required undergraduate Geotechnical Engineering course at the University of North Carolina at Charlotte. The intent is to create student-centered learning activities and interactive classroom models and/or visuals to evaluate their effect on comprehension and retention of fundamental Geotechnical Engineering concepts in the classroom while assessing preferred learning strategies. It is hypothesized that students who are challenged by conventional lecture delivery styles will benefit from a more diverse teaching method, but the use and formal assessment of these methods for a Geotechnical Engineering course is not well documented in the literature.

Participating students enrolled in this course during the first two semesters are taught using conventional lecture methods and considered to be the ‘control group’. The GCT are implemented during the last two semesters, which will be completed during the spring 2013 semester. The final two groups of participants are referred to as the ‘treatment group’. Qualitative and quantitative data are collected as part of a comprehensive evaluation plan that will be used to compare student learning outcomes in the ‘treatment’ and ‘control groups’. It is important to note that the entire course curriculum was revamped prior to the start of this project to ensure that delivery methods and teaching techniques were the only thing changed. The structure of the material (organized into ‘content modules’) remains unchanged from semester to semester.

The purpose of this project is to 1) develop effective, innovative desk-top tools (GCT) that will promote a student-centered, interactive learning environment in the classroom, 2) implement the GCT to target multiple learning styles while identifying the challenges, 3) conduct an extensive evaluation of the impact of this effort, and 4) formalize a new model for use in engineering courses and programs. This paper will address the rationale for the research initiative and describe the course design, project participants, design methodology, and evaluation plan. To date, the baseline results from this project have been collected and analyzed[1]. Collection of the data for the 'treatment group' will be completed at the conclusion of the spring 2013 semester, and will be published in a subsequent paper.

Rationale

Bloom's Taxonomy[2] and Bloom's Revised Taxonomy[3] is a multi-tiered model that defines six cognitive levels of complexity: knowledge, comprehension, application, analysis, synthesis, and evaluation[4]. Engineering students beginning their core engineering curriculum struggle to move between "knowledge" and "comprehension". Entwistle[5] discusses a less complex model that incorporates three levels of learning and can easily be applied to University curriculum. Level 1 "surface learners" have mastered the memorization technique and use the equations without deep thought or evaluation. Level 3 learners adopt an in-depth approach, striving to comprehend the concepts and the application of the new material. Level 2 "strategic learners" fall between these two levels, commonly utilizing the surface approach, but they use their Level 3 skills only when necessary. Based on experience over years of teaching this course, most engineering students at the sophomore – early junior year level are clearly "surface learners", but some of the better students fall in the Level 2 category. However, all engineering students need to be Level 2 "strategic learners" that are working towards Level 3 at this stage in their curriculum.

Within the context of the Accreditation Board for Engineering and Technology (ABET), the lowest levels in any learning hierarchy model are incompatible with required ABET program outcomes. According to ABET[6], three of the 11 required ABET student outcomes include 1) the ability to apply knowledge of mathematics, science, and engineering (ABET student outcome [a]), 2) the ability to design and conduct experiments (ABET student outcome [b]), and 3) the ability to identify, formulate, and solve engineering problems (ABET student outcome [e]). It is important that engineering faculty of all disciplines continuously push the envelope and work to elevate student learning and comprehension so that they can apply the fundamental concepts in engineering design and decision making.

The existence of various learning styles has also been well documented and multiple classification systems have been developed. For example, the Felder-Silverman model[7] separates learning styles into four dichotomous categories: student learning can be 1) sensory or intuitive, 2) visual or verbal, 3) active or reflective, and 4) sequential or global. Parallel to this student learning model, corresponding teaching styles are either 1) concrete or abstract, 2) visual or verbal, 3) active or passive, and 4) sequential or global. Evidence suggests that the current student population has a diverse learning style. Therefore, the typical teaching approach (utilizing the abstract, verbal, passive, and sequential options) prevents students from reaching their full potential[8]. Felder and Brent[8] conducted a study that sampled over 2500 college students and professors around the world, and concluded that students and faculty are overwhelmingly visual learners even though material is more often than not delivered verbally. Additionally, students tend to comprehend more using their sensory, active, and global learning skills, but the delivery of the material does not reflect these strengths. Incorporating a variety of learning styles into the classroom is a challenge, but it is necessary to enable students to achieve a higher level of comprehension. Engineering education must move towards a student-centered, interactive learning environment where the responsibility of learning is shared between student and faculty.

Alternative teaching methods have been developed in the past and some are listed below but it is important to note that these methods do not include a specially developed assessment plan and external review of their educational impact. Within the geotechnical arena, Dr. David Elton at Auburn University published a series of simple experiments that demonstrate many fundamental geotechnical concepts including effective stress, dilation, and shear strength using the concrete, visual, and active approaches[9,10]. Wartman[11] discusses the use of physical modeling to enhance geotechnical education, focusing primarily on the use of a centrifuge to demonstrate seepage and limiting equilibrium problems. This demonstration enabled students to physically control the experiment and witness failure mechanisms and transports using visual and active approaches. Likos and Lu[12] used a simple permeameter in the classroom to demonstrate contaminant transport so that students could observe the measurements to determine soil parameters. In all cases, abstract concepts were placed in the hands of students, which generated an active learning environment. In other areas of engineering, Felder[13], Unterweger[14], and Estes[15] documented their experiences with active learning exercises. In summary, most of these efforts were specific demonstrations that were incorporated for immediate impact, but the instructors did not systematically incorporate a series of planned experiments nor did they fully evaluate their impact on comprehension and retention of fundamental concepts, which is the goal of this study.

Geotechnical Concept Tools (GCT) have been developed as part of the research initiative involving a course curriculum improvement effort for a required Civil Engineering course at the University of North Carolina at Charlotte. Sometimes it takes something as simple as a 3D object in front of a student for their "light to turn on". The goal is to use innovative desktop models, three dimensional visuals, and interactive teaching techniques to increase comprehension and retention. The author of this paper previously conducted a survey of all Geotechnical Engineering faculty associated with the United States Universities Council on Geotechnical Education and Research (USUCGER) to determine what classroom innovations have been used. The author confirmed that many faculty members across the US have similar ideas, but successes and failures (if attempted) are rarely documented or disseminated. The purpose of this research initiative is to harness ideas US wide, develop effective, innovative tools that will provide students with an interactive, visual learning experience in class, implement these tools while identifying the challenges, and conduct an extensive evaluation of the impact of this effort so that a formalized model can be developed and presented to the engineering community for use in their programs.

Course Design

As part of the curriculum enhancement effort of this project, the existing Geotechnical Engineering course is organized into four main content modules: 1) Soil Structure, 2) Seepage and Effective Stress 3) Consolidation, and 4) Shear Strength. These modules and their supporting lectures were designed so that they could be taught using a more conventional lecture delivery method without the GCT during the first two semesters followed by the integration of the GCT into the course during the last two semesters. The material remains the same, but the delivery methods are altered to accommodate various learning styles. GCT will provide the students with an opportunity to visualize (in 3D), interact, and manipulate models to develop comprehension and promote a student-centered learning environment. Table 1, Table 2, Table 3, and Table 4 summarize the details of the GCT, and Table 5 displays the course schedule, divided by content module. The module and GCT number for the exercises listed in Tables 1 through 4 are depicted as footnotes on the course schedule in Table 5.

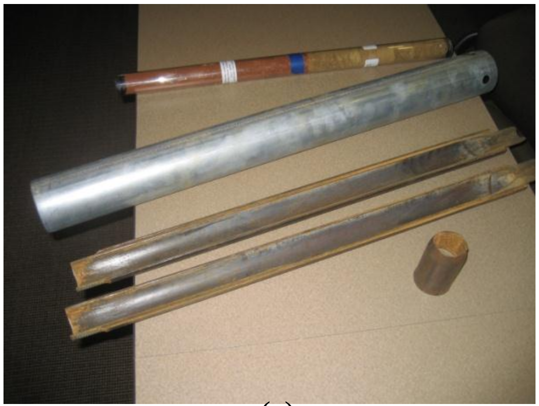
Sample photographs of some of the GCT are displayed in Figure 1 (Module 1), Figure 2 (Module 2), and Figure 3 (Module 4). GCT fall into one of three basic categories. Some GCT are distributed directly to the students as visuals that they can touch and evaluate on their own. Other GCT are larger scale 3D models that are utilized as part of a brief classroom demonstration that is designed to accentuate important concepts. The remaining GCT involve interactive and engaging classroom activities that promote a student-centered atmosphere inside the classroom. Many of these tools, models, and activities are intended to replace the dull sketches drawn on the board and conventional one-way communication methods. Because most of the GCT are classroom visuals of some kind or replace a delivery method that was used previously, there was very little (if any) additional time required to implement these changes during the first treatment group conducted in fall 2012.

Table 1. Summary of Module 1 Geotechnical Concept Tools (GCT)

Module (Number) Lecture Title
1(1) Subsurface Exploration: The first lecture is utilized to display photographs of typical drilling operations, Standard Penetration Testing (SPT), Cone Penetrometer Testing (CPT), and common sampling techniques (split spoon samplers, Shelby tubes, bag samples) to introduce the topic and stimulate their interest visually. Two of the most common soil samplers (i.e. Split Spoon Sampler and Shelby Tube) are passed around the classroom and one section of a hollow stem auger is displayed. Having the auger in the classroom enables the instructor to demonstrate how each sampler is introduced into the soil through the auger.
1(2) Subsurface Exploration: During the following recitation period, the students are divided into groups to evaluate 15 clear acrylic tubes representing 15 split spoon samples collected during a subsurface investigation. Students are informed that the 15 samples were acquired from three drilled borings, and each acrylic tube is labeled with surface elevation, sample depth, visual soil classification, boring number, and blow count information. Groups use the information on the samples to fill in the columns of pre-prepared boring logs. The transfer of information from real samples to the logs simulates the process conducted in the field by the technician. Students are expected to create a soil profile (a two dimensional view of the subsurface) from their newly created boring logs.
1(3) Phase Diagrams: All phase diagram equations and calculation steps are displayed on poster-size visuals displayed at the front of the classroom to facilitate the learning and memorizing of the equations. It is critical that the students memorize these equations due to their fundamental importance. The equations are introduced systematically while incorporating quick demonstrations when possible.

Table 1. Summary of Module 1 Geotechnical Concept Tools (GCT) (continued)

Module (Number) Lecture Title
1(4) Soil Structure and Index Properties: A 'Soil Identification Card', a set of four soil vials, and two gradation bags are provided to the students as desktop visuals during this lecture. The card displays illustrations of the main soil types and variations (i.e. clay, silt, sand, gravel), the particle size ranges in accordance with the United Soil Classification System (USCS), various particle shapes and gradations, and the structure of common clay minerals including Kaolinite and Montmorrilonite. The soil vials provide samples of fine-grained material, fine sand, coarse sand, and gravel. The gradation bags display the difference between a poorly graded soil and a well graded soil.
1(5) Soil Structure and Index Properties: To demonstrate the importance of shrink/swell properties in some specific clay minerals, a simple demonstration is conducted during this lecture. At the beginning of the lecture, large Bentonite pellets (an active clay mineral that expands significantly when hydrated) are placed in a tin pie pan elevated on rubber stoppers inside a shallow mixing pan. A student is asked to fill the mixing pan and pie pan with water to hydrate clay mineral. The change in height is monitored using a dial indicator. This simple experiment will be used to demonstrate the possible effects of high swell soils beneath or beside structures.
1(6) Soil Structure and Index Properties: To better illustrate particle-to-particle interaction, 'Soil Shear Boards' are utilized as part of a simple in-class demonstration. The boards are constructed by gluing coarse sand and fine gravel size particles to the surface of flat wooden boards with handles on the back so that the instructor can push them together (soil-to-soil) and demonstrate the frictional interaction that occurs when soil particles shear against each other. While this demonstration is best placed in the shear strength lecture (Module 4), it is first introduced in this section to illustrate the dependency of soil shape and size on particle-to-particle interactions. These boards are used continuously throughout the semester to show particle-to-particle interaction and to discuss effective stress and shear strength concepts.
1(7) Compaction: To demonstrate that fine-grained soils compact differently than coarse-grained soils, a simple in class demonstration is conducted using two clear, graduated cylinders. One cylinder is filled with loose, dry sand and the same total volume of kaolin is placed in a second graduated cylinder. For the sand sample, static pressure is applied to the surface to compact the material with very little impact. Vibration is used as an alternative method of compaction on the sand with great success, which is visually apparent to the students. For the kaolin sample, vibration is used first with little impact and static pressure is used subsequently with big impact. Furthermore, students are expected to calculate the initial and final void ratio for each sample using their knowledge of phase diagram relationships, further highlighting the range of void ratios for each soil type.



(a)

(b)

(c)

(d)

(e)

Figure 1. GCT from the Soil Structure Content Module: (a) soil samplers; (b) site investigation class exercise; (c) soil swell demonstration; (d) soil vial visuals; (e) classroom interactions

Table 2. Summary of Module 2 Geotechnical Concept Tools (GCT)

Module (Number) Lecture Title
2(1) One-Dimensional (1D) Seepage: A constant head permeameter system that includes a prepared soil test specimen and portable manometers with tubing attached is utilized in the classroom without water to create a visual learning model. This equipment is used to demonstrate fundamental 1D seepage concepts including elevation head, pressure head, total head, head loss, and hydraulic gradient pressure before covering permeability and Darcy's flow equation. The classroom model is also used to create example problems that are worked out in class interactively with the students. Because water cannot be induced inside a classroom, some information must be assumed and/or given, but the students enjoy having something set up in front of them to view and touch.
2(2) Two-Dimensional (2D) Seepage: 2D flow equations are developed from the 1D Darcy flow equation and solved using a graphical solution to Laplace's energy equation termed a flow net. While students are required to draw a flow net by hand), and learn about flow and equipotential lines displayed on paper, a fully operational flow net box inside the classroom provides a significant learning model for the students. A flow net box is constructed using 0.5" thick acrylic sheets. The box is 24" long by 18" tall by 12" deep, and the bottom of the sheet pile wall that separates the head water from the tail water is approximately 8" from the bottom of the box. Compression fittings are installed at different elevations on each end of the flow net box to adjust the constant heads on each side of the sheet pile wall to induced flow through the sand as needed. A powder dye installed in filter paper at select points at the soil surface on the upstream side is utilized to create colored flow lines through the sand as 2D seepage occurs. The system is set-up prior to class so that the 2D flow system reaches equilibrium conditions and the flow lines are almost complete when the box is carefully rolled on a cart to the classroom. The model is also used to review fundamental concepts needed to perform their calculations. For example, concepts including initial and final total hydraulic head, head loss, flow lines, and equipotential lines are defined directly on the model while a grease pencil is used to draw the equipotential lines directly on the front of the box. Subsequently, the instructor is able further demonstrate how to calculate elevation head, total hydraulic head, pressure head, and pore pressure at any point within the flow net medium.
2(3) Soil Stress: It is difficult for students to visualize both normal and shear stresses in three dimensions (3D) and then transpose the correct stress vectors to a 2D medium assuming plain strain conditions for various applications (e.g. retaining walls). A 3D wooden cube (3" sides) labeled with all normal and shear stresses is provided to each student to be used as a desktop model during this lecture. Additionally, these small models will be used during the discussion of Mohr's Circle and the 'Pole Method' to help them visualize changes in stress on various planes.
2(4) Effective Stress: Two acrylic 'Subsurface Soil Columns' (6 foot long) are constructed using various soils. Each column contains a different subsurface profile containing the unit weight information and water table location. After introducing the concepts associated with effective stress, the students are asked to work in groups of two to solve effective stress example problems using these classroom models. Students need to measure the soil depths themselves, gather the unit weight information, and make the necessary total stress, pore pressure, and effective stress calculations as part of the classroom assignment.

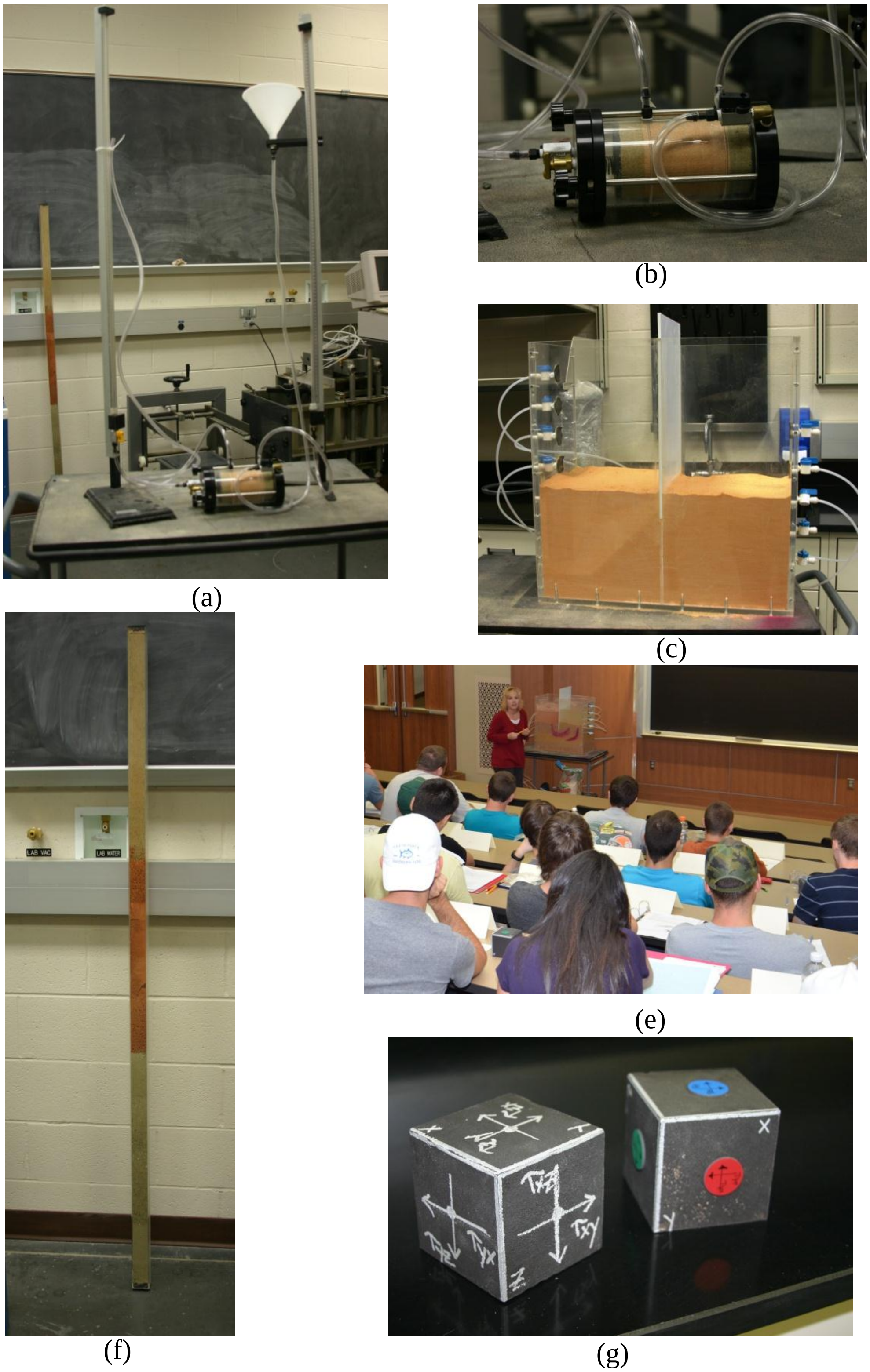


Figure 2. GCT from the Seepage – Effective Stress Content Module: (a) 1D Seepage Demonstration; (c) 1D Seepage Soil Specimen; (d) flow net box; (e) flow net demonstration; (f) soil columns; (g) soil stress cubes

Table 3. Summary of Module 3 Geotechnical Concept Tools (GCT)

Module (Number) Lecture Title
3(1) Consolidation: Due to the importance of 1D consolidation concepts, an entire lecture is utilized to cover the classic 'Spring Analogy'. This analogy compares the process that occurs during consolidation of clay soil to a spring situated inside a saturated cylinder, loaded by a piston. To set the stage for this discussion, the illustration associated with each of the four phases of this analogy will each be illustrated on a large poster that will be taped to the chalk boards positioned around the classroom. During the course of this discussion, fundamental equations for each phase will be developed to discuss the changes in pore pressure and effective stress during the consolidation process. Subsequently, an example problem will be utilized to make calculations using the same equations to demonstrate the effects on pore pressure and effective stress using numbers and a real-world application. The instructor will utilize this period to pull the information from the students as part of an interactive, engaging classroom exercise.
3(2) Consolidation: The second lecture is spent developing the most basic equation for 1D consolidation ($H_o/(1+e_o)*\Delta e$) using basic phase diagram relationships. Students will then be asked to develop the three consolidation settlement equations shown in the text using this relationship in conjunction with the consolidation curve. A soil subsurface with an applied structural load will be displayed on the board as an example problem. The structural load will be changed to reflect three different stress ranges from the initial to the final consolidation conditions (i.e. stress ranges will extend across the normally consolidated curve only, overly consolidated curve only, and across both parts of the curve). Three posters illustrating a typical consolidation curve will be hung in the classroom and the students will be challenged with calculating the initial and final effective stresses for each of the stress ranges and plotting them on each of the posters. The instructor will then interactively guide them through the development of the three main settlement equations. This exercise will enable the students to tie a real example to the development of the supporting equations with the hope that comprehension of the material will be enhanced.
3(3) Consolidation: To demonstrate the differences between a singly drained and doubly drained soil system, two clear, plastic boxes are outfitted to illustrate the differences in these subsurface profiles, and a grease marker is used to show how the longest drainage path is evaluated in each scenario.

Table 4. Summary of Module 4 Geotechnical Concept Tools (GCT)

Module (Number) Lecture Title
4(1) Shear Strength Fundamentals: The ‘Soil Shear Boards’ are incorporated into this lecture again to demonstrate the importance of normal stress on the shear strength of the soil. To create another interactive but simple way of driving this point home, the instructor asks for three volunteers (two small students and one larger student, if possible). A small student will sit on one chair and a larger student will sit on an identical chair next to them. Additionally, the larger student will hold a bucket of soil in their lap to increase their own vertical load. The third person will then act as the shear force, pushing each person in their chair across the floor. The shear force volunteer will be asked to comment on how easy or hard it was to push each person. The instructor will point out that the frictional resistance between the chair and the floor is the same for each (same μ factor) so in this analogy, the shear strength (ability to resist) is dependent on the vertical load. While this point seems obvious for people pushed on chairs, this same concept is not intuitively understood when it comes to the fundamentals of shear strength in soils so it is a simple demonstration that drives an important point home to the students.
4(2) Shear Strength Fundamentals: To illustrate the concept of liquefaction, loose, saturated sand is installed inside of a 5-gallon bucket, and a metal structure is placed on top of the soil foundation. The instructor puts a static force on the surface of the sand to show that this building appears to be on a solid soil foundation. Subsequently, the bucket is hit repetitively with a rubber mallet to simulate an earthquake force (hard and fast) and students will witness the loss of strength in this soil as the building begins to sink into the soil without any effort. The process of liquefaction and the impact on the strength of the soil is discussed.
4(3) Shear Strength Fundamentals: A triaxial cell is outfitted with a soil specimen inside the cell to provide a visual for the students as the three triaxial tests are discussed. The soil specimen is constructed using cement to hold it together since a confining pressure cannot be applied in a classroom environment. With a 3D model in the classroom, this complicated test can more easily be described for each of the three cases (CD, CU, and UU triaxial tests) and the instructor can show them how the plumbing controls the drainage of the test during the consolidation and shear phases of the test.

Table 4. Summary of Module 4 Geotechnical Concept Tools (GCT) (continued)

Module (Number) Lecture Title
4(4) Shear Strength Fundamentals: To better demonstrate the reason why a CD triaxial curve is different than a UU triaxial curve, I will fill six Ziploc bags with the same number of foam peanuts and fill them with water. Each bag represents a different test specimen generated using the same soil and initial conditions. For the first three bags associated with the CD triaxial test, I will drain most of the water out of bag 1, less water out of bag 2, and a smaller amount of water out of bag 3. A continuous water decrease is supposed to be analogous to a continuous increase in confining pressure during the first phase of the CD triaxial test. The instructor will then compress the foam peanuts inside the bag to simulate the second shear phase of the test. The goal is to demonstrate the differences in particle-to-particle interaction depending upon the initial confining pressure during the initial consolidation phase, and help the students understand how the failure curve is developed. Subsequently, no drainage will occur for the test specimens simulated in bags 4, 5, and 6, which replicates the unconsolidated phase of a UU triaxial test. The instructor will then squeeze these three bags to simulate the second shearing phase of the UU triaxial test. Through discussion, the reason for the horizontal failure curve of a UU triaxial test will become evident. This simple exercise enables the students to visualize and better comprehend soil behavior under various drainage and testing conditions.
4(5) Lateral Earth Pressure Theory: To demonstrate the concepts of "at rest", "active", and "passive" soil states, a small test is constructed using clear acrylic sides for the front and back and plywood for the two sides and bottom. The box will be filled with ¼" diameter dowels cut to the width of the box. Before the dowels are deposited in the box, a plastic sheet wall is inserted vertically in the center of the box, dividing the box into two halves. During the demonstration, the sheet wall is rotated to simulate movement of a retaining wall (passively on one side and actively on the other), and the effect of the dowels will be monitored. The class looks at the failure wedge on each side and talk about the effect of the lateral pressure (increase or decrease) for each case.
4(6) Lateral Earth Pressure Theory: A 3D model of a common earth retaining structure is used as a visual during this lecture. The model is housed inside of a box that has a clear, acrylic front side so that the profile of the structure and the soil behind it can be viewed by the students. As the instructor works an example problem in class, she will utilize a grease pencil on the front of the model to draw the pressure diagram and annotate as needed.
4(7) Slope Stability: A 3D model of an embankment is used as a visual during this lecture. The model is housed inside of a box that has a clear, acrylic front side so that the profile of the structure and the soil behind it can be viewed by the students. As the instructor works an example problem in class, she will utilize a grease pencil on the front of the model to draw an example failure surface and discuss the concepts of an equilibrium analysis.

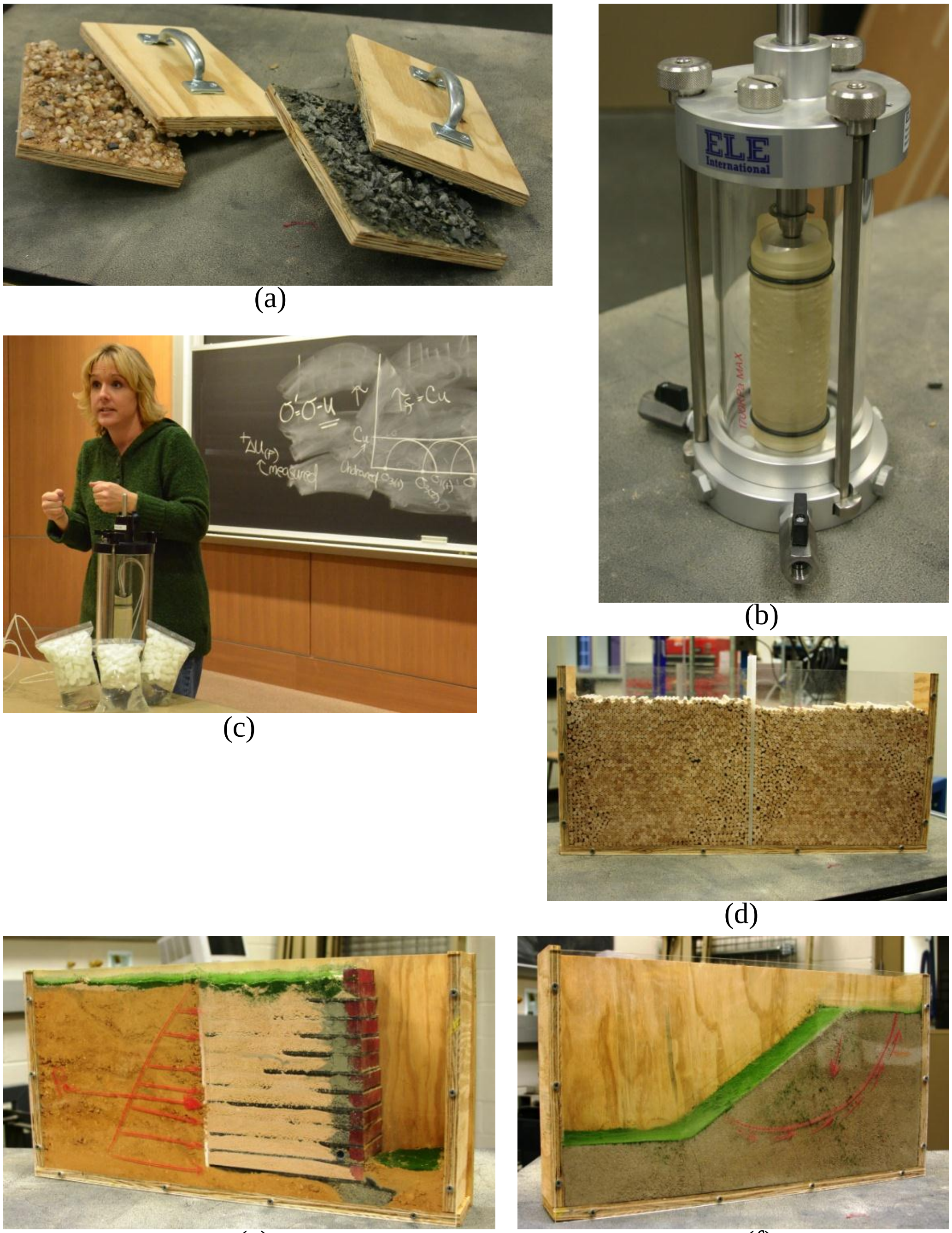


Figure 3. GCT from the Shear Strength Content Module: (a) shear boards; (c) triaxial test specimen; (d) triaxial testing demonstration; (e) lateral earth pressure demonstration; (f) slope stability demonstration

Table 5. Sample Course Schedule for CEGR 3278

Module	Day	Date	Topic
Intro	Mon	8/20	Introduction to Geotechnical Engineering
1	Wed	8/22	Subsurface Exploration[1-1]
	Fri	8/24	Required Recitation Exercise (Boring Logs)[1-2]
	Mon	8/27	Phase Diagrams[1-3]
	Wed	8/29	Phase Diagrams
	Fri	8/31	Recitation
	Mon	9/3	HOLIDAY – NO CLASS
	Wed	9/5	Soil Structure and Index Properties[1-4,1-5,1-6]
	Fri	9/7	Recitation
	Mon	9/10	Soil Structure and Index Properties[1-4,1-5,1-6]
	Wed	9/12	Soil Classification
	Fri	9/14	Recitation
	Mon	9/17	Compaction[1-7]
2	Wed	9/19	Groundwater Fundamentals and 1D Flow[2-1]
	Fri	9/21	Test 1
	Mon	9/24	Groundwater Fundamentals and 1D Flow[2-1]
	Wed	9/26	2D Flow[2-2]
	Fri	9/28	Recitation
	Mon	10/1	2D Flow
	Wed	10/3	Soil Stress and Mohr's Circle[2-3]
	Fri	10/5	Recitation
	Mon	10/8	HOLIDAY – NO CLASS
	Wed	10/10	Mohr's Circle and Stress Distribution
	Fri	10/12	Recitation
	Mon	10/15	Stress Distribution
	Wed	10/17	Effective Stress[2-4]
	Fri	10/19	Recitation
3	Mon	10/22	Consolidation[3-1]
	Wed	10/24	Consolidation[3-2]
	Fri	10/26	Test 2
	Mon	10/29	Consolidation Examples
	Wed	10/31	Time Rate of Consolidation[3-3]
	Fri	11/2	Recitation
	Mon	11/5	Time Rate of Consolidation
4	Wed	11/7	Shear Strength Fundamentals and Testing[4-1,4-2]
	Fri	11/9	Recitation
	Mon	11/12	Shear Strength Fundamentals and Testing[4-3,4-4]
	Wed	11/14	Shear Strength Fundamentals and Testing[4-3,4-4]
	Fri	11/16	Test 3
	Mon	11/19	Basics of Lateral Earth Pressure Theory[4-5, 4-6]
	Wed	11/21	HOLIDAY – NO CLASS
	Fri	11/23	HOLIDAY – NO CLASS
	Mon	11/26	Basics of Slope Stability[4-7]
	Wed	11/28	Basics of Bearing Capacity
	Fri	11/30	Test 4

Project Participants

Participants of this study include the instructor of the course (also serving as the principle investigator for this NSF funded project), consenting undergraduate students enrolled in four semesters of the required Geotechnical Engineering course at UNC Charlotte, and the four faculty members associated with the internal and external evaluation team. By the end of this project (Spring 2013), the instructor will have taught the course for the purpose of this project during two fall and two spring semesters to ensure consistency. There are typically 50-60 students enrolled in the fall and 25-35 students enrolled in the spring. There have only been 1-3 students per semester that have elected not to participate in this study in the three semesters that the course has been taught as part of the project. The authors believe that the high consent rates exist because the majority of the assessment instruments are required activities for the class (quizzes and tests) and minimal additional effort is required from the students to participate in this study (short student interviews). While this course is also offered during the summer, those students are not included as part of the student sample since the course taught during the semester is taught at an accelerated rate, which changes the dynamics of the course.

Design Methodology and Evaluation Plan

The evaluation team includes an education assessment expert from the UNC Charlotte College of Education, an internal evaluator within the same Civil and Environmental Engineering Department, and two external evaluators with engineering education evaluation expertise from other Universities across the United States. The internal and external evaluators provide on-going recommendations. The comprehensive evaluation plan evaluates the effectiveness of the implementation process and will assess the impact of GCT on comprehension (per lecture) and retention (during the course of the semester) using both "pre-post single group outcome design" and "comparison (cross-sectional) group design" methods. The skills and perceptions developed by the students that will serve as the 'control group' during the first two semesters will be compared with the skills and perceptions developed by the 'treatment group' during the last two semesters. An extensive instrumentation plan has been developed using both qualitative and quantitative instruments as described below.

Quantitative instruments include 1) pre and post student surveys, 2) short quizzes, 3) content module tests, and 4) the final exam. Quantitative data from criteria-based assessments will be analyzed using statistical procedures. The quantitative assessment design for this project is outlined in Figure 4. While all quantitative instrumentation questions on the quizzes and tests will be identical for 'control' and 'treatment' groups, it is important to note that this methodology assumes the overall intellect of the students across all four semesters are approximately equivalent and, therefore, comparable when analyzed as a 'control group' versus a 'treatment group'. This is a fair assumption since previous enrollment numbers and the student demographic information do not change significantly from year to year over such a short time period.

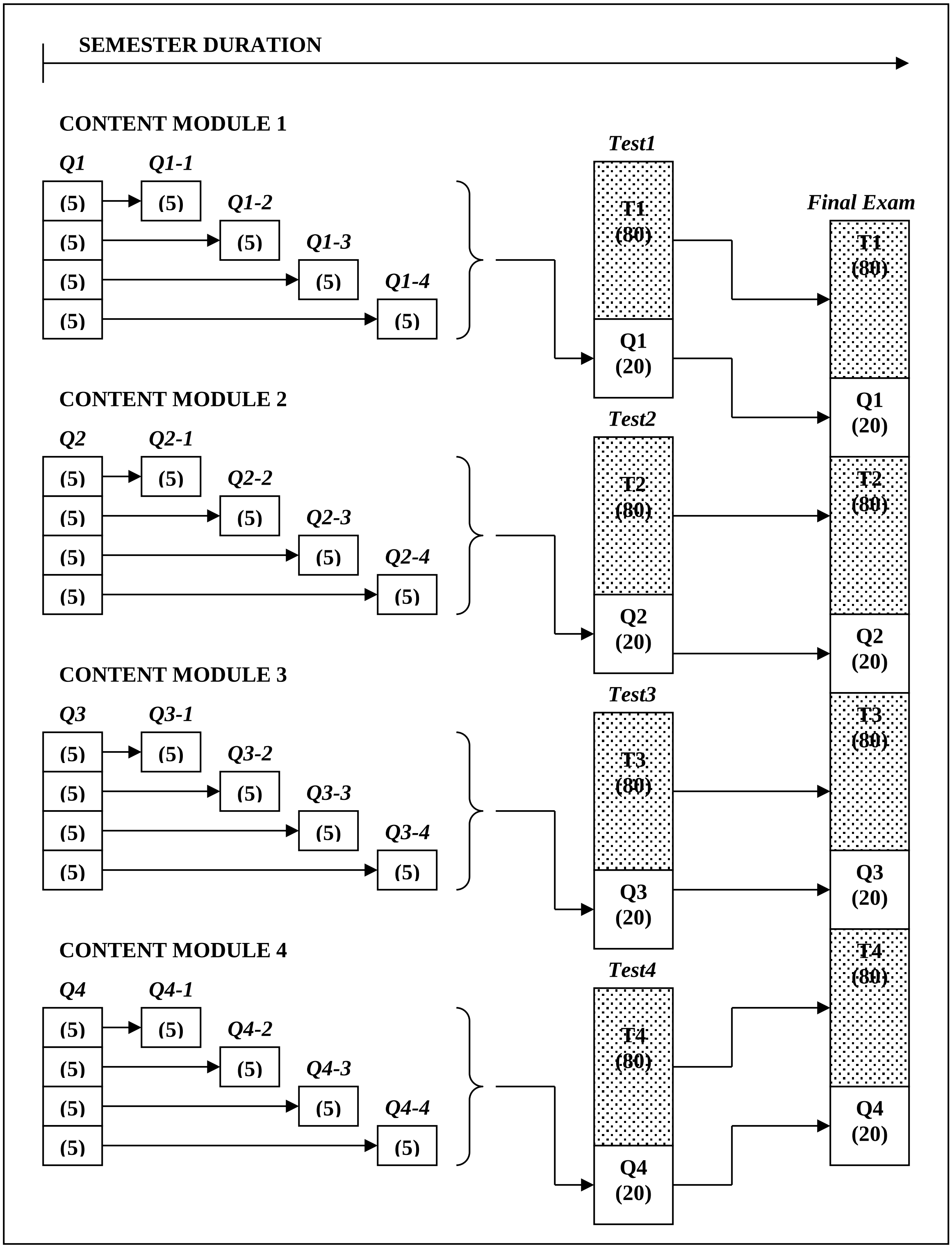


Figure 4. Quantitative Assessment Design

An 80 point, multiple-choice pre-quiz covering the material from all four content modules is conducted at the beginning of the semester to assess prior knowledge of the material and provide a baseline for each participant. It is expected that the students will have very little (if any) prior knowledge of the subject matter unless they have taken the class before and/or have geotechnical work experience. Throughout the semester, students will be given short-quizzes at the end of most lecture periods. Short answer and true-false questions will be included on these quizzes and the type and difficulty of the question(s) presented during each short-quiz will parallel the type and difficulty of the questions presented on the pre-quiz to ensure parallel form reliability. As a result, the five short-answer questions on the short-quiz can be compared to parallel questions on the pre-quiz to assess comprehension (per lecture).

A test is conducted at the end of each content module. Exactly 20% of each test will include short answer questions that are parallel in type and difficulty to the questions presented on the quizzes and the pre-quiz. The remaining portion of the test requires a higher level of problem solving ability. A final exam with the exact same format will be conducted at the end of the semester. The exam is organized to reflect equal points from each content module with 20% short answer questions with 80% work out problems that parallel the type and difficulty of the tests.

Comprehension and retention will be assessed by comparing the answers from the pre-quiz to the short answer results on the four tests and the final exam. The remaining 80% of each test will be compared to the parallel sections on the final exam to assess retention during the semester. Finally the results from the 'control group' participants during the first two semesters will be compared to the results from the 'treatment group' participants during the last two semesters to determine the numerical impact of the newly implemented GCT. It is important to note that points will be assigned to each question ahead of time in such a way that any subjectivity during the grading process is eliminated.

GCT are not implemented during the first two semesters of this study, but the same quantitative instruments will be used during all four semesters. While the instructor teaches this course every year, previous data cannot be used since the course structure and instrumentation for this project have been specifically organized so that a clear evaluation can be performed between the 'control' and 'treatment' years. Additionally, the instructor has continued to modify her curriculum, assessment tools, and teaching methods with each semester as she has developed her skills as an educator so the consistency is not present for the purpose of this study. For this reason, it is critical that an equivalent 'control group' is assessed during this project for a valid comparison with the 'treatment group'.

Qualitative data is collected from 1) observation field notes acquired by the assessment expert and the internal evaluator in the classroom, 2) instructor teaching logs that document instructor perceived successes, failures, and challenges, and 3) student interviews conducted by the assessment expert. All data will be analyzed using constant comparison method from grounded theory where statements will be grouped by common themes. The emerging themes will be adapted during the data analysis procedures. Regarding the classroom observations, the interrater reliability (agreement between the two evaluators) will be assessed to ensure consistency and un-bias in the ratings. Regarding the student interviews, five participating students will be randomly selected at the end of each content module, and their interviews will be recorded and transcribed verbatim. Common themes and the frequency of each theme will be summarized to provide the student perspectives on how well the curriculum was implemented and how well received the newly developed curriculum was. Suggestions from the students will also be considered in the refinement of the curriculum.

Student data on criteria-based assessments will be analyzed in two ways: (1) participating students in each semester will be considered as individual samples and (2) participating students in each academic year (fall and spring) will be considered as a complete sample. This will identify possible differences between the students who enroll in the fall and the spring semesters (if any) and will also aid in the formative evaluation. If no differences are identified between the fall and spring semesters for each year, then all students in a single academic year will be merged into one large group to increase the sample size and the statistical power of the analyses. Mixed design Analysis of Variance (ANOVA), also known as Split-Plot ANOVA, as well as t-tests will be used for statistical analyses, and a family-wise alpha-level of 0.05 will be used for statistically significant difference.

Repeated-measures t-tests will be employed to measure statistically significant gains of 'student comprehension per lecture' measured by the short-quizzes against their prior knowledge of the fundamental concepts measured by the pre-quizzes. Recall that each pre-quiz evaluates their knowledge of the material to be covered over the following comparative content module, and the mean student scores on each quiz will be compared to the mean scores for each corresponding section in the pre-quiz (recall Figure 5).

Repeated-measures t-tests will also be employed to measure statistically significant gains of 'student retention during the course' as measured by the four tests given each semester against their performance on the final exam. The final exam contains all contents covered in each of the previous quarterly tests, and the mean student scores on each quarterly test will be compared to the mean scores for each corresponding section in the final exam.

Independent sample tests will be employed to compare students' comprehension and retention of the material in the same way as described for repeated-measures but not within the same group of the students. Instead, 'treatment group' student data from the second two semesters will be compared to 'control group' student data collected during the first two semesters, cross-sectionally. Table 6 summarizes the details of the extensive project evaluation plan.

The results collected from the first two semesters including the 'control group' are presented in detail in a companion paper[1]. Analyses of these data suggests that while all students gained significantly in the content knowledge, they want more real-world examples that can help them make the connection between what they learn from the textbook and what they are expected to do in the actual civil engineering field.

Table 6. Summary of the Project Evaluation Design

Objectives	*Outcomes*	*Methods*	*Data Sources*	*Schedule*
Effective Implementation	GCT Implementation Plan Course Syllabus with Learning Objectives Fidelity of the Implementation Increased Student Participation & Satisfaction	Teaching Logs & Reflections (Qualitative)	Instructor: Dr. Warren	After Each Implementation Course Lecture (as necessary) During Year 2
		Observation Field Notes (Qualitative)	Internal Evaluators: Dr. Wang Dr. Anderson	4 Times Per Semester During Year 2
		Student Interviews (Qualitative)	5 Random Participating Students	4 Times Per Semester During Both Years
Assessed Comprehension (Per Lecture)	Improved Comprehension Of Fundamental Geotechnical Concepts	Pre-Quizzes (Quantitative)	Participating Students	4 Times Per Semester During Both Years
		Quizzes (Quantitative)	All Students	16 Times Per Semester During Both Years
		Student Interviews (Qualitative)	5 Random Participating Students	4 Times Per Semester During Both Years
Assessed Retention (During Semester)	Improved Retention Of Fundamental Geotechnical Concepts	Quizzes (Quantitative)	All Students	16 Times Per Semester During Both Years
		Tests (Quantitative)	All Students	Four Times Per Semester During Both Years
		Final exam (Quantitative)	All Students	End of Semester During Both Years

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