A Preliminary Analysis of the Impact of Geotechnical Concept Tools (GCT) Integrated into a Civil Engineering Classroom

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Dr. Kimberly Warren is an Associate Professor at the University of North Carolina at Charlotte who specializes in the field of Geotechnical Engineering, a discipline of Civil Engineering. She holds her Civil Engineering degrees from Virginia Tech and North Carolina State University. Her disciplinary research involves the use of geosynthetic materials (polymeric materials) incorporated into Civil Engineering Structures including roadways and earth retaining structures. Due to her strong passion for teaching, Dr. Warren pursued educational research opportunities in recent years and was awarded an NSF TUES grant, which she is currently completing with hopes of continuing her work in this area. Dr. Warren has been awarded the UNC Charlotte College of Engineering teaching award for her dedication and excellence in teaching.

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Dr. Wang is an associate professor of educational research at the University of North Carolina at Charlotte. He received a National Science Foundation (NSF) grant, Development, Implementation, and Assessment of Geotechnical Concept Tools, as a Co-Principal Investigator and served as an independent program evaluator for four other federally funded research grants: (1) Developing Standards-Based Mathematics Teachers; (2) Behavior and Reading Improvement Center; (3) Translating Inquiry-Based Learning into Environmental Biotechnology Courses at Four Institutions; and (4) Assessment Practices to Support Mathematics Learning and Understanding for Students. Dr. Wang also received six state/regional grants: (1) Expert Witness for Center for Civil Rights Leandro Intervention; (2) High School Challenge: Achievement Gap between At-Risk and Not-At-Risk Students; (3) Elementary School Students' Self-Efficacy Beliefs and Self-Regulated Learning Strategies in Learning English as a Second Language; (4) Self-efficacy Beliefs and Self-Regulated Learning Strategies of Children Learning English as a Second Language; (5) Improving Basic Literacy Skills and Social Behavior of Urban At-Risk Kindergartners through Intensive Early Reading Intervention and Parental Involvement; and (6) Standardizing the Test of English for Graduate Students. The first two grants were based on the analysis of the large-scale longitudinal data from North Carolina Education Research Data Center (NCERDC) located in the Center for Child and Family Policy at Duke University. He has published 6 books, 10 book chapters, and 60 journal articles. Of the 76 publications, 45 were in the areas of reading or mathematics and were related to factors such as student, teacher, principal, superintendent, and community characteristics. He also had more than 40 paper presentations at national and international academic conferences. Dr. Wang received the 2008 American Educational Research Association (AERA) Distinguished Paper Award.

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Introduction

The fundamentals of soil mechanics, which are taught as part of a Geotechnical Engineering course that is required in most Civil Engineering programs across the U.S., are difficult for undergraduates to comprehend using conventional lecture methods. While engineering students can easily 'utilize' equations to solve engineering problems, they are not as motivated to 'comprehend' the equations or fundamentals. It is sometimes difficult for them to put the engineering fundamentals in the context of a big picture engineering application given the standard lecture format. 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 at UNC Charlotte, interactive classroom tools referred to as Geotechnical Concept Tools (GCT) were incorporated into the curriculum and the results of their implementation were formally evaluated using 'Control' and 'Treatment' Group design. The intent of this initiative was to create student-centered learning activities and interactive classroom models and/or visuals to evaluate their effect on the comprehension and retention of fundamental Geotechnical Engineering concepts in the classroom. It is hypothesized that students who are challenged by conventional lecture delivery styles will benefit from a more diverse teaching method that targets multiple learning styles, but the use and formal assessment of these methods for a Geotechnical Engineering course has not been well documented in the literature.

Participating students enrolled in this course during the first two semesters (i.e., the Control Group) were taught using conventional lecture methods. The GCT were implemented during the last two semesters and these students were referred to as the Treatment Group. Qualitative and quantitative data were collected during all four semesters as part of a comprehensive evaluation plan. The instructor used an inquiry-based approach so that the students were motivated to take notes during the lecture while maintaining constant communication and interaction with the instructor.

The purpose of this National Science Foundation funded project was to 1) develop effective, innovative desk-top tools (GCT) that would 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. Warren and Wang provide a more detailed discussion of this project [19] and the baseline results[18]. The purpose of this paper is to present a preliminary analysis of the final results comparing the Treatment Group to the baseline results collected from the Control Group to determine what impact (if any) the

GCT had on the comprehension and/or retention of the course curriculum. Most of the analysis presented in this paper is associated with the quantitative instrumentation.

Research Rationale

The inquiry-based pedagogy model is based on Bloom and Krathwohl's (1956) Taxonomy[4] and Bloom's Revised Taxonomy[3], which focuses on student-centered learning activities and interactive skills. Bloom's taxonomy, which has been used in education as a valid benchmark that measures a student's level of understanding, consists of six cognitive levels including 1) knowledge, 2) comprehension, 3) application, 4) analysis, 5) synthesis, and 6) evaluation. The American Society for Civil Engineers (ASCE) adopted Bloom's taxonomy as the basis for defining levels of achievement associated with the body of knowledge necessary for entry into the practice of civil engineering at the professional level[2]. ASCE (2008) states that Civil Engineering students are expected to remember previously learned material (i.e., knowledge), to grasp the meaning of material (i.e., comprehension), to use learned material in new and concrete ways (i.e., application), to break down material into its component parts so that its organizational structure may be understood (i.e., analysis), to put material together to form a new whole (i.e., synthesis), and to judge the value of material for a given purpose (i.e., evaluation)[2].

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[1], three of the required 11 ABET student outcomes include 1) the ability to apply knowledge of mathematics, science, and engineering (i.e., ABET student outcome [a]), 2) the ability to design and conduct experiments (i.e., ABET student outcome [b]), and 3) the ability to identify, formulate, and solve engineering problems (i.e., 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.

Alternatively, Entwistle[8] discusses a less complex model that incorporates three levels of learning that 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, the author of this paper feels that 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.

In addition to content learning, the inquiry-based pedagogy claims to develop such important skills as: critical thinking, problem solving strategies, self-regulated learning, and collaborative learning in teams. These skills are not always assessed in traditional, lecture-based classrooms. Some studies suggested that the inquiry-based approach was an effective pedagogy to help students become self-regulated learners and develop problem-solving skills[13,16,21]. Other studies, however, noted some weakness of this pedagogy. Dahlgren and Oberg[5] argued that the students generated very few solution-oriented questions (only 6% of the total number of questions). The majority of the questions generated by the students happened to be encyclopedic (31%) and meaning-oriented (24%). The authors maintained that making use of encyclopedic questions indicates surface approach learning. This argument was echoed by Nuy[15] who believe that as far as content knowledge was concerned, the traditional methods may be more realistic. He further maintained that even though the traditional approach may lack motivation, it taught basic science in a more coherent way.

The existence of various learning styles has also been well documented and multiple classification systems have been developed. For example, the Felder-Silverman model[12] 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[11]. Felder and Brent[11] 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. Based on experience and feedback from students, sometimes it takes something as simple as a 3D object in front of a student for their "light to turn on". 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[6,7]. Wartman[20] 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[14] 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[10], Unterweger[17], and Estes[9] 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.

Course Design and Participants

As part of the curriculum enhancement effort of this project, the existing Geotechnical Engineering course was 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 for the Control Group during the first two semesters, followed by the integration of the GCT into the course during the last two semesters of the project for the Treatment Group. The material remained the same, but the delivery methods were altered to accommodate various learning styles for the Treatment Group. The goal was to use innovative desktop models, three dimensional visuals, and interactive teaching techniques to increase comprehension and retention of difficult concepts. Figure 1 displays examples of some of the GCT utilized during this study. More details are provided in a previous paper by the Warren and Wang[19].

Participants of this study include the instructor of the course, consenting undergraduate students enrolled in four semesters of a required Geotechnical Engineering course, and the four faculty members associated with the internal and external evaluation team. A total of 162 students registered for a required Civil Engineering undergraduate course at a large southeastern university participated in this study over two spring and two fall semesters. While this course is also offered during the summer, those students were not included as part of the student sample since the course taught during the summer is taught at an accelerated rate by a different instructor, which changes the dynamics of the course.

The student sample consistently had 85% ± 1% males and 15% ± 1% females during each of the four semesters evaluated. Of all the participants, 35% and 18% participated during the first and second semesters, representing the Control Group, and 33% and 14% participated during the third and fourth semesters, representing the Treatment Group. Approximately 88% - 97% of all registered students elected to participate during this study, depending upon the semester. The distribution of the student demographics per semester is presented in Table 1. Of all the students who reported their status in the program, one student was a freshman, 106 were juniors, and 42 were seniors. The distribution of age was approximately normal with a mean of 22.45 years and a standard deviation of 3.72 years.

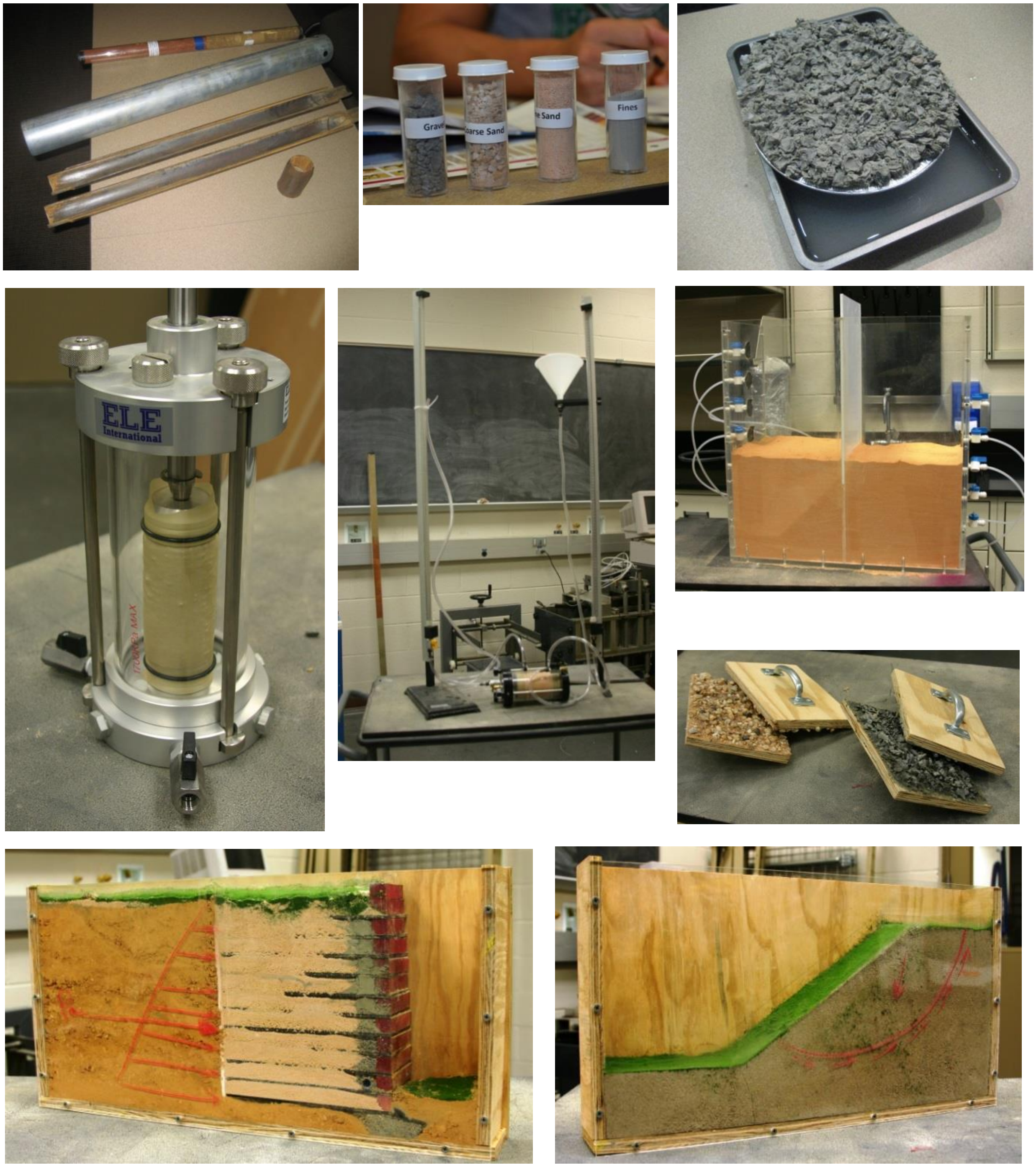

Figure 1. Samples of the Geotechnical Concept Tools (GCT)

Table 1. Participating Student Demographics

	Semester 1 (Fall)	**Semester 2 (Spring)**	**Semester 3 (Fall)**	**Semester 4 (Spring)**
American Indian or Alaskan Native	0.0%	0.0%	0.0%	0.0%
Asian or Pacific Islander	5.7%	0.0%	0.0%	0.0%
Black (not of Hispanic origin)	9.4%	3.2%	3.4%	7.7%
Hispanic	3.8%	0.0%	10.3%	11.5%
White (not of Hispanic origin)	64.2%	83.9%	72.4%	73.1%
Unknown or Other	17.0%	12.9%	13.8%	7.7%
Number of Students Enrolled	58	33	56	26
Number of Participants	56	29	54	23

Design Methodology and Evaluation Plan

The evaluation team included an independent education assessment expert from the UNC Charlotte College of Education, an internal evaluator recruited from the UNC Charlotte Civil and Environmental Engineering Department, and two external evaluators with engineering education evaluation expertise from other Universities. The comprehensive evaluation plan, which includes both quantitative and qualitative assessment instrumentation, was developed to evaluate the effectiveness of the implementation process and assess the impact of GCT on comprehension and retention using both "pre-post single group outcome design" and "comparison (cross-sectional) group design" methods. The skills and perceptions developed by the students in the Control Group were compared with the skills and perceptions developed by the Treatment Group.

While all quantitative instrumentation questions on the quizzes and tests were identical for the Control and Treatment Groups, it is important to note that this methodology assumes the overall intellect of the students across all four semesters was approximately equivalent and, therefore, comparable when analyzed as a Control Group versus a Treatment Group. This is a fair assumption since enrollment numbers and student demographic information do not typically change significantly from year to year. Additionally, while the instructor teaches this course every year, previous data could not be used since the course structure and instrumentation for this project were specifically organized so that a clear evaluation could be performed between the Control and Treatment years. The quantitative instrumentation included 1) pre and post student surveys, 2) four content module tests, and 3) the final comprehensive exam. GCT were not implemented during the first two semesters of this study, but the same quantitative instruments were used during all four semesters. Quantitative data from criteria-based assessments summarized in Figure 2 were analyzed using statistical procedures.

An 80 point, multiple-choice, pre-quiz covering the material from all four Content Modules was conducted at the beginning of each semester to assess prior knowledge of the material and provide a baseline for each student participant. It was expected that the students would have very little (if any) prior knowledge of the subject matter since most (if not all) students were taking this course for the first time. A test was conducted at the end of each Content Module. Exactly 20% of each test included short answer questions that were parallel in type and difficulty to the questions presented on the pre-quiz and the short answer questions on the final exam. The remaining portion of the test required a higher level of problem solving ability. Likewise, the final comprehensive exam was organized to reflect equal points from each Content Module with 20% short answer questions and 80% work out problems that parallel the type and difficulty of the Content Module tests.

Comprehension and retention was 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 was 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 were 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 the amount of credit/distribution of points was assigned to each question ahead of time in such a way that any subjectivity during the grading process was eliminated.

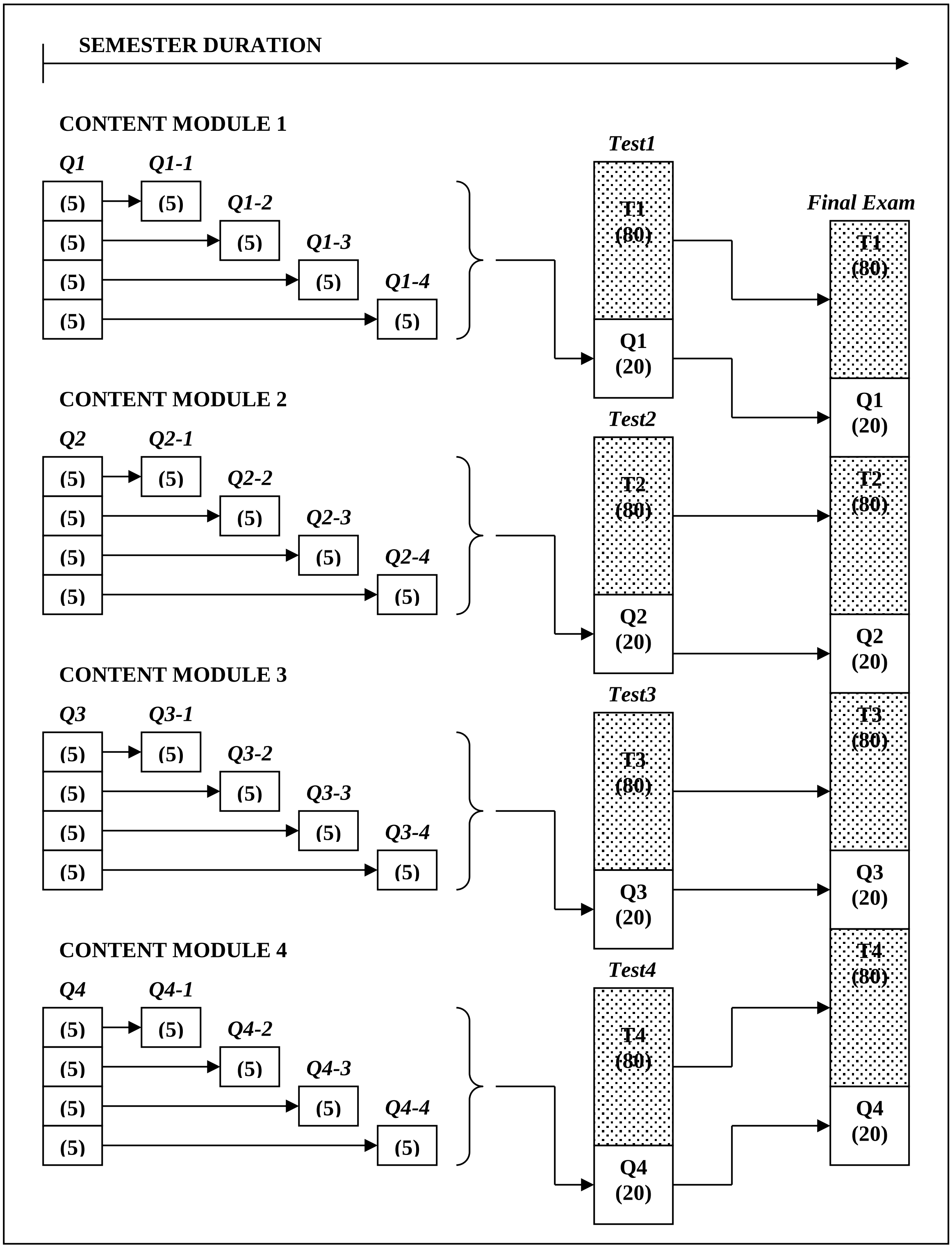

Figure 2. Quantitative Assessment Design

In addition to the quantitative instruments displayed in Figure 2, students filled out three surveys at the beginning and at the end of each semester. First, the 'Student Self-Efficacy for Cognitive Ability' survey was based on Bloom's taxonomy, which is a multi-tiered model that evaluates six levels of cognitive ability including knowledge, comprehension, application, analysis, synthesis, and evaluation. The reliability and validity of this survey has been tested in previous research[3]. This survey included 30 questions that measured the students' degree of self-efficacy to remember and understand course content as well as to solve, analyze, evaluate, and create a problem related to soil structure, seepage, effective stress, consolidation, and shear strength. Students were asked to rate on a five-point Likert scale where '1' stands for "cannot do at all" and '5' stands for "certainly can do". Second, the 'Student Self-Efficacy for the Application of Knowledge' survey included 21 questions developed by the researchers to measure the student's self-efficacy to accomplish tasks associated with the content in the course. Students were asked to rate the same five-point Likert scale. Lastly, the 'Self-Regulated Learning Strategies' survey included 13 questions that were developed according to Zimmerman's social cognitive theoretical framework of self-regulation to measure student use of self-regulated learning strategies in the college[22]. Students were asked to report the frequency that they used the 13 strategies described in the survey where '1' stands for "not at all" and '5' stands for "all the time".

Student data on criteria-based assessments were analyzed in two ways: (1) participating students in each semester were considered as individual samples and (2) participating students in each academic year (fall and spring) were considered as a complete sample. This process evaluated possible differences between the students who enroll in the fall and the spring semesters (if any) and also aided in the formative evaluation. Because no differences were identified between the fall and spring semesters for each year, all students in a single academic year were 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, was used for statistical analyses, and a family-wise alpha-level of 0.05 was used for statistically significant difference. The final exam contains all contents covered in each of the previous quarterly Content Module tests and the pre-quiz, which makes it possible to compare the mean student scores on the pre-quiz and each quarterly Content Module test with the mean scores for each corresponding section on the final exam. Table 2 summarizes the details of the extensive project evaluation plan.

Table 2. 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	After Each Implementation Course Lecture (as necessary) During Year 2
		Observation Field Notes (Qualitative)	Internal Evaluators	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

Qualitative data was 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. While this paper does not focus on the qualitative data associated with this study, these data were analyzed using a constant comparison method from grounded theory where statements were grouped by common themes. The emerging themes were adapted during the data analysis procedures. Regarding the classroom observations, the interrater reliability (agreement between the two evaluators) was assessed to ensure consistency and un-bias in the ratings. Regarding the student interviews, five participating students were randomly selected at the end of each content module, and the interviews of those students who elected to participate were recorded and transcribed verbatim. Common themes and the frequency of each theme were summarized to provide the student perspectives on how well the curriculum was implemented and how well received the newly developed curriculum was. These data will be presented in a subsequent journal paper.

Discussion of Results

To determine whether the GCT had an impact on student knowledge gain, the tests and final exam for this study were designed to have two types of questions including 1) multiple choice, short answer questions worth 20% and 2) in-depth, workout problems worth 80%. First, the data collected from the short answer questions on the pre-quiz given at the beginning of each semester (i.e., the baseline data) were compared to the data collected from the short answer questions on each corresponding Content Module test as well as the data collected from the parallel short answer questions on the final exam. An equal number of short answer questions were included on the final exam for each Content Module. Figure 3 displays the combined mean score for all short answer questions on the entire pre-quiz, each Content Module test, and the final exam, comparing the Control Groups and Treatment Groups. Each bar represents the combined percent of correct answers for a particular 'Group' and quantitative instrument.

Using the mean scores displayed in Figure 3, it is important to note that the baseline knowledge level (i.e., the score associated with the pre-quiz) is lower for the Treatment Group. This is important because the authors are attempting to assess the difference between the level of baseline knowledge and the knowledge level during and at the completion of the course using the Content Module tests and the final exam instruments, respectively. The goal was to determine whether the GCT impacted the comprehension (short term) and/or retention (semester long) of the fundamental geotechnical engineering concepts. Based on the data presented in Figure 3, there is some indication that the achieved difference in knowledge is higher for the Treatment Group for all Content Module tests as well as the final exam. Table 3 provides the calculated differences in combined mean scores between the pre-quiz and each subsequent testing instrument. Based on the consistent increase in knowledge gain, it can be concluded that the GCT likely had some impact on student performance and their comprehension/retention of the course fundamentals when evaluating the data associated with the short answer questions.

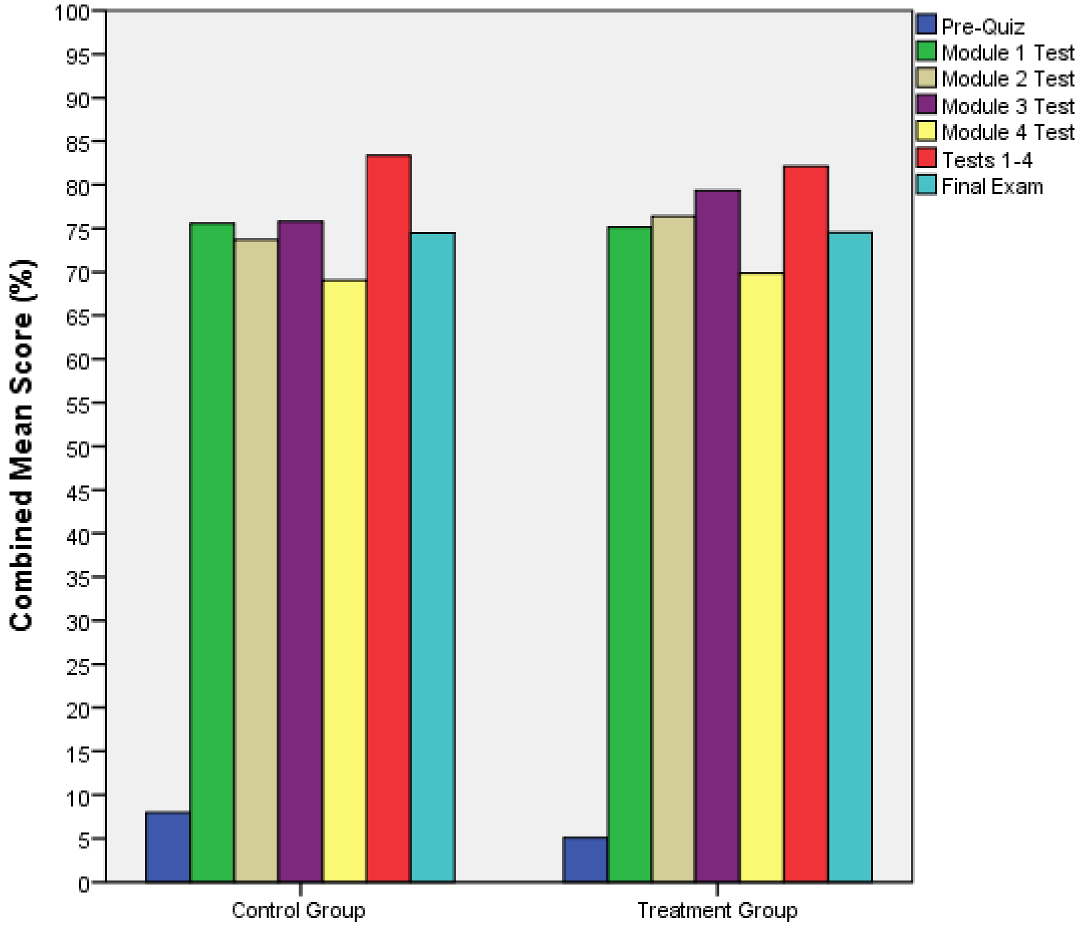

Figure 3. Short Answer Question Combined Student Performance on the Pre-Quiz, Content Module Tests, and the Final Exam, Comparing the Control Group to the Treatment Group

Table 3. Summary of the Differences in the Combined Mean Scores

	Difference in the Combined Mean Score (%) [Test or Final Exam – Prequiz]	
	Control Group	Treatment Group
Content Module Test 1	57.53	65.60
Content Module Test 2	66.95	71.67
Content Module Test 3	74.02	77.93
Content Module Test 4	67.26	68.73
Final Exam	66.52	69.43

Based on the statistical analysis conducted by the assessment expert, the repeated measures ANOVA showed a significant interaction between Treatment and Control Groups when comparing the data collected from the Module 1 short answer questions on the pre-quiz to the short answer questions on the Content Module 1 test, $F(1, 155) = 2.09$, $p = .01$, partial $\eta^2 = 0.01$. In other words, the Treatment Group students' gains were higher than the students in the

Control Group during the first section of this course, referred to as Content Module 1. Note that the pre-quiz bar in Figure 3 is representative of all questions asked on the pre-quiz and not divided up by Content Module so the trends shown on Figure 3 should not be utilized as a visual for this analysis. However, this same interaction (i.e., comparison of data collected from representative short answer questions on the pre-quiz to the short answer questions on the corresponding Content Module test) was not statistically significant for the other Content Modules: Content Module 2, $F(1, 155) = 3.45$, $p = .07$, partial $\eta^2 = 0.02$; Content Module 3, $F(1, 155) = 2.84$, $p = .09$, partial $\eta^2 = 0.02$; and Content Module 4, $F(1, 155) = 0.51$, $p = .48$, partial $\eta^2 = 0.003$. Similarly, the interaction effect between the Groups of the overall performance of students using the data collected from the short answer questions on the pre-quiz versus the final exam was not statistically significant either, $F(1, 155) = 2.09$, $p = .15$, partial $\eta^2 = 0.01$.

The associated descriptive statistics displayed in Table 4 indicate that the final exam results of the Treatment and Control Groups were not statistically different from each other. Even though there was not a significant difference in performance between the Groups during the final evaluation of this course, it should be noted that the Treatment Group had a baseline level (as measured by the pre-quiz) that was lower than the baseline level of the Control Group. Therefore, it can be concluded that the Treatment Group had a larger overall difference in performance.

In summary, while there was not a significant difference in the short answer question scores measured on the final exam by each Group, there was a larger overall difference in the scores (baseline to end of semester) on the final exam by the Treatment Group, indicating that they did achieve a higher gain. Additionally, the statistical difference in the scores reported for the Content Module 1 test aligns well with the high number and type of GCT introduced during Content Module 1. Compared to other sections of this course, there were more GCT utilized during Content Module 1 and they were hands-on tools that were passed out to the individual students. Some GCT in the subsequent Content Modules served more as interactive demonstrations and/or visuals that were located at one point in the classroom. Based on this data, it appears that the inclusion of specific types of GCT had a positive impact on knowledge and skill gain during the semester. It could be interpreted that a GCT that is put in the hands of a student has a higher impact than one utilized as a visual and/or model in the classroom.

While the data collected from the short-answer questions were analyzed in the previous paragraphs, the remaining 80% of each test instrument was delivered using more in-depth, work out engineering problems associated with the fundamentals from the course. To further assess the impact of the GCT on student knowledge and skills and determine whether the impact of the GCT depends on the type of problem/challenge and/or level of thinking required, the combined results of the data collected from the work out problems on each Content Module test were compared to the combined results of parallel questions on the final exam. The workout problems were designed to require a higher level of analysis from the student.

Figure 4 displays the combined mean score of the workout problems on each test adjacent to the combined mean score of the parallel workout problems on the final exam, comparing the Control Group to the Treatment Group. Note that for each Content Module test displayed in Figure 4, the corresponding final exam score is represented by the bar directly to the right of it.

Based on the data presented in Figure 4, it appears that there is more of an increase in knowledge between the Content Module 1 test and the parallel questions on the final exam for the Treatment Group and the overall scores are slightly higher. There is also more of an increase in knowledge between the Content Module 2 test and the parallel questions on the final exam for the Treatment Group. For Content Module 3, it appears that the students performed worse on the final exam in comparison to the Content Module 3 test for both Groups, but the decrease in final exam score is much less for the Treatment Group, indicating an improvement. This pattern does not hold true for Content Module 4. It is interesting to note the decrease in long term performance on the final exam in comparison to Content Module test 3. For this Content Module, it is important to point out that there is very little interaction with GCT during this section of the course. In other words, the 'student engagement factor' is the lowest during Content Module 3, which could explain the trend displayed for this Module on Figure 4. Overall, it appears that the GCT had a positive impact on comprehension/retention of the material.

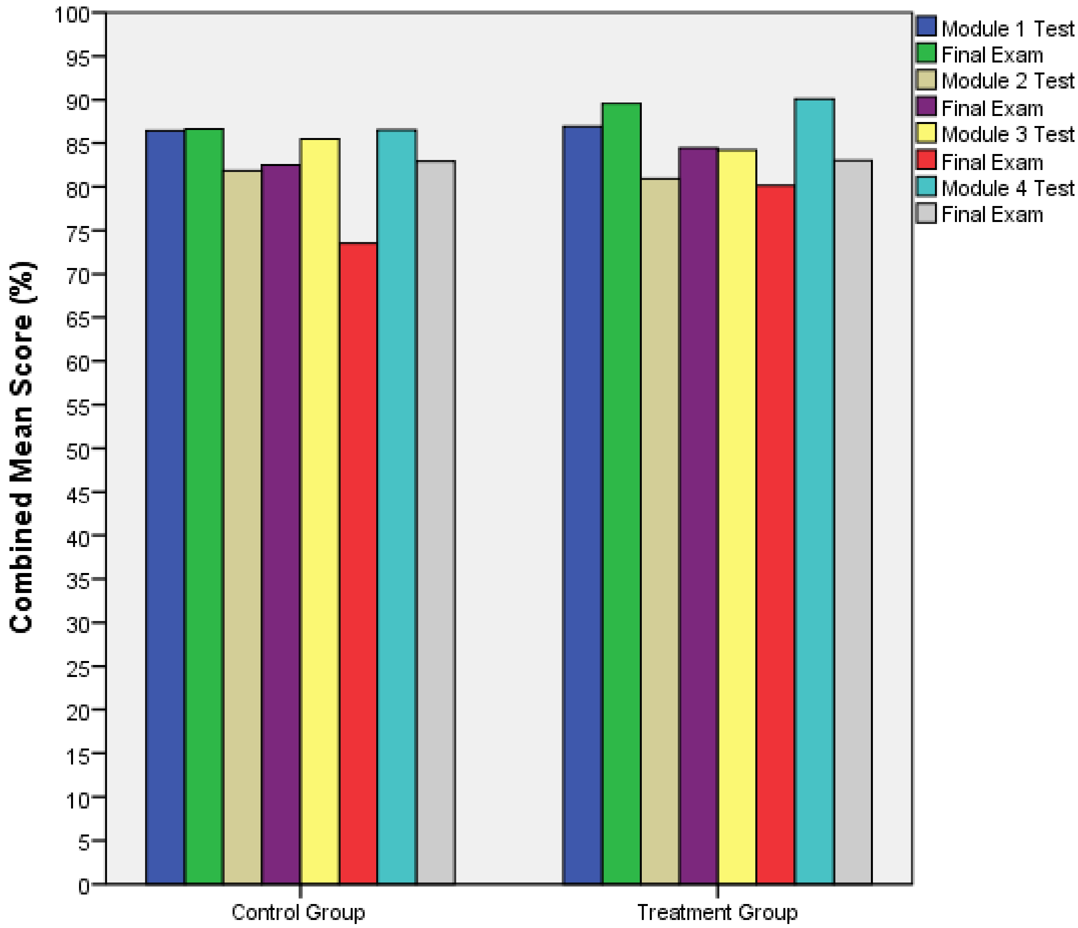

Figure 4. Workout Problem Combined Student Performance on each Content Module Test Compared to the Parallel Questions on the Final Exam, Comparing the Control Group to the Treatment Group

Based on the statistical analysis performed by the assessment expert, the differences between student performances on the workout problems in the final exam versus the workout problems in each Content Module test were not statistically significant for Content Modules1 and 2 in either Group: Content Module 1, F (1, 155) = 1.62, p = .20, η^2= .01; and Content Module 2, F (1, 155) = 2.95, p = .09, η^2=0.02. However, the difference was significant for Modules 3 and 4. For both treatment and control groups, student performance on the final exam was statistically worse than the performance measured by the Content Module 3, F (1, 155) = 22.08, p < .001, η^2= .13 and Content Module 4, F (1, 155) = 29.53, p < .001, η^2= .16. Similar to a previous statement, the GCT that were incorporated into Content Modules 1 and 2 were more hands-on and less 'demonstrative'. The data presented in this paper confirms that the integration of the GCT had a positive impact, but the method used to engage the students makes a difference. Evidence suggests that the current student population has a diverse learning style. Recall that the typical teaching approach (utilizing the abstract, verbal, passive, and sequential methods) prevents students from reaching their full potential[11]. These data imply that comprehension and retention increases when the teaching style is more visual and sensory.

Changes in Student Self-Efficacy Beliefs and Self-Regulated Learning Strategies

It is important to address the reliability and validity of the surveys that were administered. The 'Student Self-Efficacy for Cognitive Ability' survey (based on Bloom's taxonomy) was deemed reliable: the Cronbach's alpha was .99 for all items and .94, .95, .97, .96, .96, and .96 for the sub constructs of knowledge, comprehension, application, analysis, synthesis, and evaluation, respectively. The 'Student Self-Efficacy for the Application of Knowledge' survey was also reliable with a Cronbach's alpha value of .96. Although the Cronbrach's alpha value for the 'Self-Regulated Learning Strategies' survey was slightly lower, .81, it is still considered reliable especially when one considers that students do not always use all categories of strategies all the time. The Pearson correlation coefficients between the pre-quiz results and responses to the surveys suggest that these surveys had concurrent validity: .29 for the first survey, .27 for the second survey, and .31 for the self-regulated learning strategies survey. The Pearson correlation coefficients between the final exam score and the responses to the surveys also support the concurrent validity: .38 for the first survey, .46 for the second survey, and .29 for the self-regulated learning strategies survey. These Pearson correlation coefficients were statistically significantly different from zero, p < .05.

Descriptive statistics for the measurement of student self-efficacy beliefs and their use of self-regulated learning strategies are presented in Table 5. Combining all four semester together, students' self–efficacy to perform tasks learned in the course from the beginning to the end of the semester increased significantly, F (1, 98) = 998.44, p < .001, η^2= .91. The same trend was found for each of the subscales as follows. Their self-efficacy to remember concepts related to soil structure, seepage, effective stress, consolidation, and shear strength: F (1, 98) = 1010.49, p < .001, η^2= .91. Their self-efficacy to understand concepts related to soil structure, seepage, effective stress, consolidation, and sheer strength: F (1, 98) = 819.18, p < .001, η^2= .89. Their self-efficacy to solve a problem related to soil structure, seepage, effective stress, consolidation, and sheer strength: F (1, 98) = 980.59, p < .001, η^2= .91. Their self-efficacy to analyze a problem related to soil structure, seepage, effective stress, consolidation, and sheer strength: F (1, 98) = 734.42, p < .001, η^2= .88. Their self-efficacy to evaluate a problem related to soil structure, seepage, effective stress, consolidation, and sheer strength: F (1, 98) = 869.05, $p < .001$, $\eta^2 = .90$. Their self-efficacy to create a problem related to soil structure, seepage, effective stress, consolidation, and sheer strength: F (1, 98) = 611.90, $p < .001$, $\eta^2 = .86$. The students' self-efficacy for the application of knowledge covered in this course was also statistically stronger at the end of the semester than in the beginning of the semester, F (1, 98) = 944.57, $p < .001$, $\eta^2 = .91$. It is important to note that the interaction effects between the Control and Treatment Groups and their changes in self-efficacy beliefs were not statistically significant, which means that all students gained self-efficacy beliefs equally as a result of taking this course.

Interestingly, the students also reported significantly more use of self-regulated learning strategies after taking this course, F (1, 97) = 18.92, $p < .001$, $\eta^2 = .16$ even though this was not a focus of the course. Of all the13 strategies listed on this survey, strategy 1 (self evaluate one's own work), strategy 3 (planning), strategy 5 (taking notes in class), and strategy 11 (re-read for review) were notably recognized by students.

While this paper does not focus on the qualitative data because the authors can more definitively evaluate differences between the Control and Treatment Groups using quantitative date, the qualitative data from student interviews and informal feedback from the students to the instructor overwhelming suggest that students like the use of GCT and benefit immediately from their presence in the classroom. During a formal interview, one student said, "when I just see the lecture, I don't know how that's going to apply to the real world, but when I see the example, it clicks together with what's going on in the class." Based on the qualitative data collected, the use of real-world examples helps the students make the connection between what they learn from the textbook and what they are expected to do in the actual Civil Engineering field. Additionally, those students who were taking the lab course simultaneously found this course extremely helpful because they had more exposure to the use of the knowledge.
A more formal presentation of the qualitative feedback will be included in a subsequent journal paper.

The results from this study also suggest that students who are self-regulated, keep their goals in mind, know what they are doing and why they are doing it, feel competent to do what they are supposed to do, and do their work as expected will do well in the class. The implications of these findings suggest the importance of motivation, self-regulation, and self-efficacy in the student learning process. While content knowledge is important, keeping students motivated, self-regulated, and efficacious will help students reach their academic and career goals.

Table 4. Descriptive Statistics for Student Performance on Content-Based Tests

	Control Group		Treatment Group	
	Mean	SD	Mean	SD
PreT1	17.80	14.25	9.53	10.44
PreT2	6.77	8.10	4.73	8.01
PreT3	1.95	4.63	1.40	4.24
PreT4	1.83	5.30	1.13	3.14
T1Pre	75.56	13.87	75.13	12.14
T2Pre	73.72	14.80	76.40	13.37
T3Pre	75.98	14.98	79.33	12.58
T4Pre	69.09	13.97	69.87	11.45
T1Fin	86.41	13.23	86.90	13.45
T2Fin	81.84	15.09	80.91	16.65
T3Fin	85.47	16.13	84.19	15.92
T4Fin	86.51	10.28	90.10	8.60
FinT1	86.61	13.15	89.55	12.09
FinT2	82.50	13.00	84.44	16.40
FinT3	73.54	24.58	80.13	25.30
FinT4	82.91	14.78	83.01	14.54
Test1	82.36	12.59	85.04	10.36
Test2	76.07	13.55	75.79	14.58
Test3	80.32	17.63	83.22	14.13
Test4	81.55	12.54	84.38	8.81
Final	80.30	10.17	82.28	12.15
Testaverage	83.42	9.52	82.11	9.23
FinPre	74.45	11.71	74.53	10.19
Prequiz	7.09	6.57	4.20	5.43

Note. (a) Prequiz is the pretest at the beginning of the semester, and FinPre is part of the final exam that matches the prequiz; (b) PreT1 is part of the prequiz that corresponds to the end of Module 1 test, T1Pre is part of the end of Module 1 test that corresponds to the prequiz, T1Fin is part of end of Module 1 test that corresponds to the final exam, and FinT1 is part of the final exam that corresponds to end of Module 1 test; (c) PreT2 is part of the prequiz that corresponds to the end of Module 2 test, T2Pre is part of the end of Module 2 test that corresponds to the prequiz, T2Fin is part of end of Module 2 test that corresponds to the final exam, and FinT2 is part of the final exam that corresponds to end of Module 2 test (d) PreT3 is part of the prequiz that corresponds to the end of Module 3 test, T3Pre is part of the end of Module 3 test that corresponds to the prequiz, T3Fin is part of end of Module 3 test that corresponds to the final exam, and FinT3 is part of the final exam that corresponds to end of Module 3 test; (e) PreT4 is part of the prequiz that corresponds to the end of Module 4 test, T4Pre is part of the end of Module 4 test that corresponds to the prequiz, T4Fin is part of end of Module 4 test that corresponds to the final exam, and FinT4 is part of the final exam that corresponds to end of Module 4 test; (f) Final is the total final exam score; (g) testaverage is the average score for all four module tests.

Table 5. Descriptive Statistics for Measurement of Student Self-Efficacy and Self-Regulated Learning Strategies

	Control Group		Treatment Group	
	Mean	SD	Mean	SD
Self-Efficacy Apply Pre	1.39	.79	1.25	.57
Self-Efficacy Apply Post	4.36	.43	4.12	.57
Self-Efficacy Cognition Pre	1.53	.86	1.42	.54
Self-Efficacy Cognition Post	4.32	.51	4.00	.61
Remember Pre	1.59	.84	1.52	.58
Remember Post	4.43	.54	4.13	.64
Understand Pre	1.59	.85	1.50	.66
Understand Post	4.42	.54	4.10	.68
Solve_Problem Pre	1.54	.89	1.41	.52
Solve_Problem Post	4.32	.51	4.11	.70
Analyze_Problem Pre	1.51	.91	1.40	.59
Analyze_Problem Post	4.37	.61	4.02	.69
Evaluate_Problem Pre	1.53	.96	1.38	.57
Evaluate_Problem Post	4.37	.58	4.02	.63
Create_Problem Pre	1.44	.85	1.29	.56
Create_Problem Post	4.02	.64	3.59	.74
SRL Strategy Pre	3.45	.59	3.54	.58
SRL Strategy Post	3.66	.41	3.72	.50

Acknowledgements

This project was funded by the National Science Foundation TUES Program through the Division of Undergraduate Education (Proposal 0837647).

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