AC 2011-1255: USE OF SOIL BEHAVIOR DEMONSTRATIONS TO INCREASE STUDENT ENGAGEMENT IN A SOIL MECHANICS COURSE

Harry Cooke, Rochester Institute of Technology

Harry Cooke is an associate professor in the Civil Engineering Technology program at Rochester Institute of Technology where he teaches courses in geotechnical engineering, construction materials, pavements, and mechanics of materials. His research interests include geotechnical engineering, civil engineering materials, and engineering education.

Use of Soil Behavior Demonstrations to Increase Student Engagement in Elementary Soil Mechanics

Abstract

An important aspect of the geotechnical engineering discipline in civil engineering is the understanding of the physical behaviors of different soil types. This understanding underlies and supports the engineer's intuition and insights on how a particular soil may impact the design and construction of a project. The first exposure of undergraduate civil engineering students to soil behavior typically occurs in an introductory soil mechanics course. In this class, it is common for students to be taught about key soil behaviors using verbal explanations in lecture and written explanations provided in textbooks, perhaps supplemented with diagrams or video. However, these approaches often do not provide students with a good "physical feel" for the behaviors and hence may not promote a deep appreciation and understanding of the topic. Even if there is a laboratory component of the course, the laboratory exercises often focus on testing procedures for measuring soil properties rather than a thorough exploration of soil behaviors and their causes.

The purpose of the study presented here is to investigate the effectiveness of using physical demonstrations of key soil behaviors in soil mechanics lectures, along with follow-up discussions, to improve undergraduate student engagement and understanding of these behaviors. Some prior investigators have reported success in using physical demonstrations to improve student learning experiences in some undergraduate engineering courses. Others reported similar successes in engineering exploration programs for K-12 students, some of which included soil behavior experiments. However, none of these prior studies focus specifically on using soil behavior demonstrations in undergraduate soil mechanics lectures to increase student engagement and learning.

In the current study, five different soil behavior demonstrations from the book Soils Magic by Elton[1] were integrated into the lectures of an undergraduate soil mechanics course. For each demonstration, students were first asked to predict what would happen before seeing the experiment. They then observed the demonstration being performed and, lastly, were asked to explain the reasons for the behavior observed. Student responses to survey statements about the soil behavior demonstrations clearly indicate that an overwhelming majority of them felt the experiments were interesting and effective, made them think more about the soil behaviors investigated, and helped them to better understand the behaviors. The performance of students on two examinations given during the term was generally better in the course section that used the demonstrations, as opposed to prior sections that did not, which suggests some improvement in learning. Student ratings of the course and instructor at the end of the term were higher for the class section where the experiments were used indicating improved student perceptions of the course and, perhaps, increased student interest in the material. This encouraging study data, along with the fact that nearly all of the students taught with the soil behavior demonstrations agreed that they should be used in future offerings of the course, confirm the effectiveness of this approach for increasing student engagement and learning of this topic.

Background and Purpose

Understanding the physical behavior of different soil types is critical to geotechnical and civil engineering design. Some examples of fundamental soil behaviors of importance include the contractive and dilative behaviors of granular soils like sands, or the ability of clays to absorb and hold water.

Typically an undergraduate civil engineering student's first exposure to soil behavior occurs in an introductory soil mechanics class normally taken in the sophomore or junior year. Oftentimes soil behavior is explained to students verbally in lecture, perhaps using a Powerpoint presentation and some schematic diagrams, as well as through written descriptions of the behavior provided in textbooks. Although there is often a laboratory associated with the first soil mechanics course, the labs normally focus on testing procedures used for soil identification or measurement of other engineering properties and typically do not provide an exploration and explanation of the physical behaviors of the soil. As a result, students often do not develop a good physical understanding of certain soil behaviors.

One potential solution investigated in this paper to provide students with a better understanding of soil behavior, and also generate interest and enthusiasm about the subject, is to introduce simple physical demonstrations of that behavior in lecture to complement the concepts being discussed. The idea of using teaching methods that more completely engage the physical senses and attention of students, and are effective for a variety of learning styles, has been recognized and promoted by numerous authors and teaching workshops, such as the Excellence in Civil Engineering Education (ExCEEd) program sponsored by ASCE. Wankat and Oreovicz[2], in Teaching Engineering, state that "Classroom demonstrations used during lecture can provide a concrete learning experience and the chance for discovery". The benefits of using demonstrations in lecture to enhance teaching are also espoused by Lowman[3] in Mastering the Techniques of Teaching. Lowman[3] states that the use of props "to illustrate the subject at hand" is essential in a discipline like engineering. He also indicates that good lectures are effective for engaging and motivating students to learn.

Several prior studies have been conducted by other investigators on the impact of physical demonstrations on student engagement and understanding in engineering and related courses, such as math. Klosky and VanderSchaaf[4], Lesko et al.[5], Graves[6], Pearce et al.[7], Song and Bannerot[8], and Kumpaty and Ficken[9] have all performed investigations where they introduced demonstrations to complement topics being discussed in the lecture of an undergraduate engineering (or engineering related) course. As part of these studies, they obtained limited student feedback regarding the impacts of those experiments on understanding and interest in the course material. In all of the studies, the demonstrations were well received. Oftentimes students commented that the demonstrations helped them to visualize, understand, and apply the concept that was being discussed. In the case of Klosky and VanderSchaaf[4], the rating of the instructors for their mechanics course, based on end-of-course evaluations, went up for the instructors use of visuals (rating went up from 4.4 to 4.7 out of 5.0, with 5.0 being the best rating) and the effectiveness of the teaching (rating went up from 4.1 to 4.5 out of 5.0) when experiments were used to complement lecture concepts. Forsberg[10] and Perrin[11], who also introduced demonstrations into their engineering related courses, indicate that the experiments made the classroom more lively and helped to increase student interest and comprehension of topics. However, there was no direct student feedback or performance data collected by either Forsberg[10] or Perrin[11].

There is at least one case in the literature where the impact of using physical demonstrations in lectures had mixed results. Lesko et al.[5] reported that the use of hands-on statics demonstrations in a lecture class of about 35 undergraduate students resulted in no improvement in the performance of the class on examinations compared to classes where the demonstrations were not used. The authors hypothesize that this lack of improvement may have resulted from the students not performing the experiments themselves, but rather they watched the experiments being performed.

Physical demonstrations to illustrate different types of soil behavior are readily available and have been used by others to spark interest in the topics of geotechnical and civil engineering. Elton[1] provides instructions for 27 different experiments that demonstrate different soil behaviors in a book entitled Soils Magic. Although Elton[1] indicates in the preface of the book that the experiments can be used to generate interest in soils for all age levels, including K-12 and college students, published studies on the impact of the experiments on student interest and understanding of soil behavior have only been conducted, to the author's knowledge, at the K-8 level. Elton et al.[12] and Hanson et al.[13] both report success in using "Soils Magic" experiments for students at the K-8 level to generate the interest of this group in engineering and civil engineering. Elton et al.[12] report that the overall response of students at the K-8 level was very positive, with the students responding with a rating of 3.75, or higher, out of 4.0 (4.0 being the highest/best rating) to the two survey statements that "Soils Magic was fun" and "Soils Magic was interesting". Both groups of authors reported that the most effective "Soils Magic" demonstrations were the ones where students were actually physically involved or assisted with the experiments.

The primary purpose of the current study presented in this paper is to investigate whether the performance, and follow-up discussion, of soil behavior demonstrations (from the book Soils Magic) in the lectures of an introductory, undergraduate soil mechanics course will 1) increase student thinking about soil behavior and 2) improve student understanding of the soil behaviors illustrated by the experiments. A secondary purpose of the study is to evaluate whether the demonstrations will increase student interest in, and improve student perceptions of, the soil mechanics course and, perhaps as a result, improve overall student learning in the course. The basis for evaluating the effects of the demonstrations on student thinking, understanding, and performance is direct student feedback, as well as a comparison of student performance between cohorts where the experiments were and were not used. This study will supplement information from other studies on the benefits of using physical demonstrations to improve learning.

Details of Study

The current study investigating the impact of soil behavior demonstrations on student engagement and learning was conducted by the author in the one section of an undergraduate Elementary Soil Mechanics course he taught in 2009 in the civil engineering technology (CET) program at Rochester Institute of Technology (RIT). This 10-week-long course is typically taken in the second year of the five-year undergraduate CET program. The course section taught by the author in 2009, which had 19 students enrolled and served as the experimental group, incorporated five different soil behavior demonstrations (from Soils Magic by Elton[1]) into the lectures. The experiments, which are explained in greater detail in Table 1 (including details of some enhancements made), included:

- Dilation of dense sand,
- Swelling of clay,
- Clay with saltwater,
- Capillary rise in soils, and
- Liquefaction of loose, saturated sands.

Other than these five soil behavior demonstrations, the teaching methods and materials used for the experimental group in 2009 were essentially the same as those used in sections of the same course taught by the author the four prior years he was at RIT. The 2008 course section, which was the last one taught by the instructor without the demonstrations, served as the control group for this study since it is the cohort closest timewise to the experimental group, which should reduce any minor differences in course delivery. The experimental group, control group, and prior course sections all completed seven homework assignments, six different laboratories along with three written lab reports, two 50-minute-long examinations, and one two-hour-long final examination as part of their coursework. The 19 students in the experimental group had a mean grade point average of 2.92 out of 4.00. The control group had 30 students with a mean grade point average of 3.05. A two-tailed t-test performed between these mean grade point averages gave a t-value of 0.832 indicating no significant difference between the two groups for the probability of 95 percent used.

Each of the five soil behavior demonstrations listed in Table 1 were integrated into the lectures given to the experimental group when concepts related to that soil behavior were being discussed in class. To maximize student engagement and interest, a specific sequence of events was commonly followed. First, the basic concepts for the soil behavior being studied were introduced and discussed in lecture just prior to the demonstration being done. Second, the experiment was set-up in class and an explanation was provided of the materials to be used and what was going to be done with or to those materials. At that time the students were asked to discuss what they thought the outcome of the demonstration would be and the reason for that predicted outcome. When possible, students were polled regarding what would happen. Third, the demonstration was performed, typically with the help of a student volunteer from the class, and observations were made of what happened. Fourth, the class was asked to state what they observed to happen and why that behavior was observed based on the concepts discussed related to soil behavior. A follow-up discussion was held with the class, as needed, to clarify any remaining concepts regarding the soil behavior and its causes.

Student feedback regarding the effectiveness of each demonstration for engaging their thinking and improving their understanding of a particular soil behavior was obtained using a simple seven question survey completed by students at the end of a lecture in which a demonstration was performed. Information on the impacts of the experiments on student interest and perceptions of the soil mechanics course was obtained by making use of feedback given on the

Table 1 - Soil Behavior Demonstration Details

Demonstration	Observed Behavior	Explanation of Behavior	Reference*; Enhancements
1. Dilation of dense sand	a) Water level goes down in observation tube connected to saturated, dense sand when dense sand is squeezed; b) water level goes up when loose sand is squeezed	a) Dense sand dilates when squeezed (and sheared) causing increase in total soil volume and volume of (saturated) voids; b) loose sand contracts when squeezed causing decrease in total soil volume and volume of (saturated) voids	Pages 10 – 13; Added a second sample consisting of loose sand where water rises when squeezed.
2. Swelling of clay	Dry, bentonite clay pellets in a pan swell significantly when continually exposed to a source of water.	Electrically-charged bentonite clay particles are able to attract and hold a thick, double layer of water molecules around themselves	Pages 29 – 30; Swollen, wet clay dried in oven to show that it does not go back to original size
3. Clay with saltwater	a) Dry, bentonite powder mixed with saltwater has viscous, fluid-like consistency; b) bentonite powder mixed with tap water has thick, sticky, putty-like consistency	a) Positive sodium ions from salt are attracted to, and offset, negatively-charged clay particles so water molecules not attracted to clay; b) tap water has "no" sodium ions and therefore water attracted to and held by clay	Pages 25 – 26; Clay with salt-water is poured out while bowl containing clay with tap water is turned upside down
4. Capillary rise in soils	Height of capillary water rise in tube filled with 0.075 mm size sand is several inches higher than rise in tube filled with 0.150 mm size sand	Height of capillary water rise is inversely proportional to size of voids in soil which is directly related to particle size, therefore the smaller sand size has smaller voids and higher capillary rise.	Pages 34 - 35
5. Liquefaction of loose, saturated sand	a) "Structure" on loose, saturated sand sinks below surface and water pressure in sand goes up when sand is vibrated; b) "structure" on dense saturated sand stays on surface and water pressure does not go up when sand vibrated	a) Vibration (and shearing) of loose, saturated sand causes sand particles to shift which transfers load to pore water and increases water pressure thereby reducing effective stress and causing liquefaction b) Vibration of dense sand results in minimal particle shift and "no" water pressure increase and therefore no liquefaction.	Pages 20 – 22; Added dense sand sample; standpipes attached to sides of containers filled with sand; water flows out of standpipe when loose sand vibrated.

*Note: Reference page numbers are from Soils Magic by Elton[1] standard RIT "Student Evaluation of Instruction" forms completed by enrolled students at the end of a course. Lastly, the impact of the demonstration approach on the overall, broad-based learning of students in soil mechanics was inferred by comparing student scores on homework, laboratory reports, and examinations to prior years when the demonstrations were not used, with a particular focus on the experimental (2009) and control (2008) groups.

Student Response to Demonstrations

Subjective, quantitative student feedback on the effectiveness and usefulness of the five soil behavior demonstrations used in lectures was obtained by having students complete a survey where they responded to seven statements concerning each demonstration. Possible responses to the statements, and the corresponding five-point Likert scale rating (given in parentheses) associated with each one, included strongly disagree (= 1), disagree (= 2), neutral (= 3), agree (= 4), or strongly agree (= 5). In addition, space was provided at the bottom of each survey where students could provide written comments regarding things they liked about each demonstration and things they disliked or thought could be improved.

Table 2 shows an example of the survey statements used to get feedback for the dilation of dense sand demonstration, as well as the response data from students. For each statement the number,

Table 2 – Survey Results for Dilation of Dense Sand Demonstration

Survey Statement	Number and Percentage of Students Selecting Likert Rating 1 – 5*					Mean Rating
	1	2	3	4	5	
1. I found this demonstration to be interesting.	0 0%	0 0%	0 0%	7 41.2%	10 58.8%	4.56
2. I was surprised water level in tube went down instead of up when dense sand squeezed.	1 5.9%	1 5.9%	1 5.9%	4 23.5%	10 58.8%	4.24
3. Demonstration clearly showed one of effects associated with dilation of dense sand.	0 0%	0 0%	0 0%	6 35.3%	11 64.7%	4.65
4. Demonstration and follow-up discussion made me think more about dilation of dense sand compared to just a verbal discussion.	0 0%	0 0%	2 11.8%	6 35.3%	9 52.9%	4.41
5. Demonstration and follow-up discussion was effective for helping me understand dilation behavior of dense sand.	0 0%	0 0%	1 5.9%	8 47.1%	8 47.1%	4.41
6. Follow-up discussion of demonstration was useful for improving my understanding of dilation behavior observed in demo.	0 0%	0 0%	0 0%	8 47.1%	9 52.9%	4.53
7. I recommend that this demonstration be used again when teaching soil mechanics.	0 0%	0 0%	0 0%	4 23.5%	13 76.5%	4.76

*Note: In rating system 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

and corresponding percentage, of students (out of the seventeen students who completed the survey) who selected a particular Likert response is shown. In addition, the mean Likert scale rating obtained for each statement is provided in the last column. As seen from Table 2, statements 1 to 3 focus primarily on the effectiveness of the demonstration in showing the effects of the soil behavior being studied (in this case dilation of dense sand). Statements 4 to 6 investigate whether the experiment and follow-up discussion were effective in promoting student thinking and understanding about the soil behavior. Lastly, statement 7 seeks the student's opinion about continuing to use the demonstration in future sections of the soil mechanics course and thereby provides some additional insight into the students' feelings about its usefulness.

Survey statements used to get student feedback on the other four demonstrations used in the course were basically the same as those shown in Table 2. Due to the similarity of the student responses obtained for a given survey question for all five demonstrations, mean ratings were calculated for each survey question based on the responses from all five experiments. These mean ratings are provided in Table 3, including the mean percentage of respondents who selected particular Likert responses to a statement (obtained by averaging the percentage of students who selected that response for all five demonstrations) and the overall mean Likert rating for that statement (obtained by averaging the mean Likert rating for that statement for all five demonstrations). The range of the mean Likert ratings for a statement based on all five

Table 3 – Mean and Range of Responses to Survey Questions for All Five Demonstrations

Survey Statement	Mean Percentage of Students Selecting Likert Rating 1 – 5*					Mean Likert Rating	
	1	2	3	4	5	Overall Mean	Range
1. I found this demonstration to be interesting.	0	0	0	44.5	55.5	4.59	4.42 – 4.67
2. I was surprised at the soil response and effects observed in the demonstration.	1.2	5.0	17.3	33.4	43.1	4.12	3.67 – 4.56
3. Demonstration clearly showed one of the effects associated with the soil behavior.	0	0	0	23.0	77.0	4.77	4.65 – 4.83
4. Demonstration and follow-up discussion made me think more about the soil behavior compared to just a verbal discussion.	0	0	8.8	34.9	56.3	4.47	4.32 – 4.72
5. Demonstration and follow-up discussion was effective for helping me understand the soil behavior.	0	0	7.9	33.6	58.5	4.51	4.41 – 4.67
6. Follow-up discussion of demonstration was useful for improving my understanding of the soil behavior observed in demo.	0	0	4.6	38.0	57.4	4.53	4.42 – 4.73
7. I recommend that this demonstration be used again when teaching soil mechanics.	0	0	1.1	29.6	69.3	4.68	4.56 – 4.83

*Note: In rating system 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

demonstrations is also provided. The number of respondents who completed a survey for each experiment ranged from 15 to 19 students, with the total number of respondents completing surveys over the five demonstrations being 87.

The overall mean Likert rating of 4.59 and 4.77 shown in Table 3 for statements 1 and 3, along with the fact that 100 percent of the students agree or strongly agree with these statements, clearly indicate that the soil behavior demonstrations were interesting and were effective at showing the effects of the behaviors being investigated. The slightly lower overall mean Likert rating of 4.12 for statement 2, along with the 76 percent of students who agree or strongly agree with this statement, indicates that a majority of the students were surprised at the soil response observed. So typically there was a "surprise factor" associated with each of the experiments.

The overall mean Likert rating of about 4.5 for statements 4 to 6 of the surveys, along with the 90 percent or more of the respondents who either agreed or strongly agreed with these statements, clearly indicates that the demonstrations and follow-up discussions made students think more about the soil behaviors investigated than would have happened with just a verbal lecture. This approach also helped them understand the reasons behind those behaviors, with the follow-up discussions being particularly helpful as indicated by the response to statement 6.

The overwhelming positive reaction of the students to these demonstrations is further confirmed by their response to survey statement 7, where on average 99 percent of the students agreed or strongly agreed that the soil behavior experiments should continue to be used when teaching soil mechanics. This feedback, along with the responses to the other statements, supports the usefulness of these experiments in helping students think about and understand soil behavior.

Forty written comments were provided by students on the surveys concerning the things they liked about the five demonstrations used in lecture. An overview of those remarks is presented here. Several students appreciated the hands-on and visual nature of the demonstrations and a few commented that this approach was helpful for them as visual learners. Students also indicated that the experiments effectively showed the concepts that were being discussed in lecture. In some cases they noted their surprise at the way the soil behaved, and a few enjoyed being given a chance to predict the soil behavior. A few students indicated they liked the humor that was used in some demonstrations, particularly for the swelling of clay experiment where a volunteer "chef" from the audience "baked" a pie by exposing dry bentonite clay pellets in a pie pan to water. No written comments were received from students indicating that they disliked aspects of the demonstrations. One student suggested that the visual aspects of the sand dilation experiment could be improved by replacing the black bicycle tire tubing, which contained the sand, with clear tubing. The written remarks support the usefulness of the demonstrations for teaching students about soil behavior. The comments are also consistent with the positive feedback other investigators received when they implemented demonstrations in their classes.

Student Reactions to Course

No data or student feedback was collected in this study that directly addresses whether the use of soil behavior demonstrations increased student interest in, and improved student perceptions of, the soil mechanics course. However, information from the standard RIT "Student Evaluation of

Instruction" survey given at the end of the course indirectly provides insight into these issues. Of the seventeen questions to which students respond on the evaluation of instruction form, the six questions listed below could provide insight into changes in student interest and perceptions of the course as a result of using the five demonstrations.

1. How well have the course objectives been fulfilled?
2. What is your present feeling about how much you learned in this course?
3. How was the instructor's presentation of the course material?
4. How well did the instructor motivate you to learn?
5. Overall how would you rate this course?
6. Overall how would you rate this instructor?

Student responses to each of these questions are transformed into a numerical Likert rating with 1 being the lowest (worst) rating possible and 5 being the highest (best).

Figures 1 to 3 show plots of the mean student responses to questions 1 and 2, 3 and 4, and 5 and 6, respectively, for the Elementary Soil Mechanics course sections taught by the author over the years 2005 (author's first year at RIT) to 2009. The number of students completing the surveys,

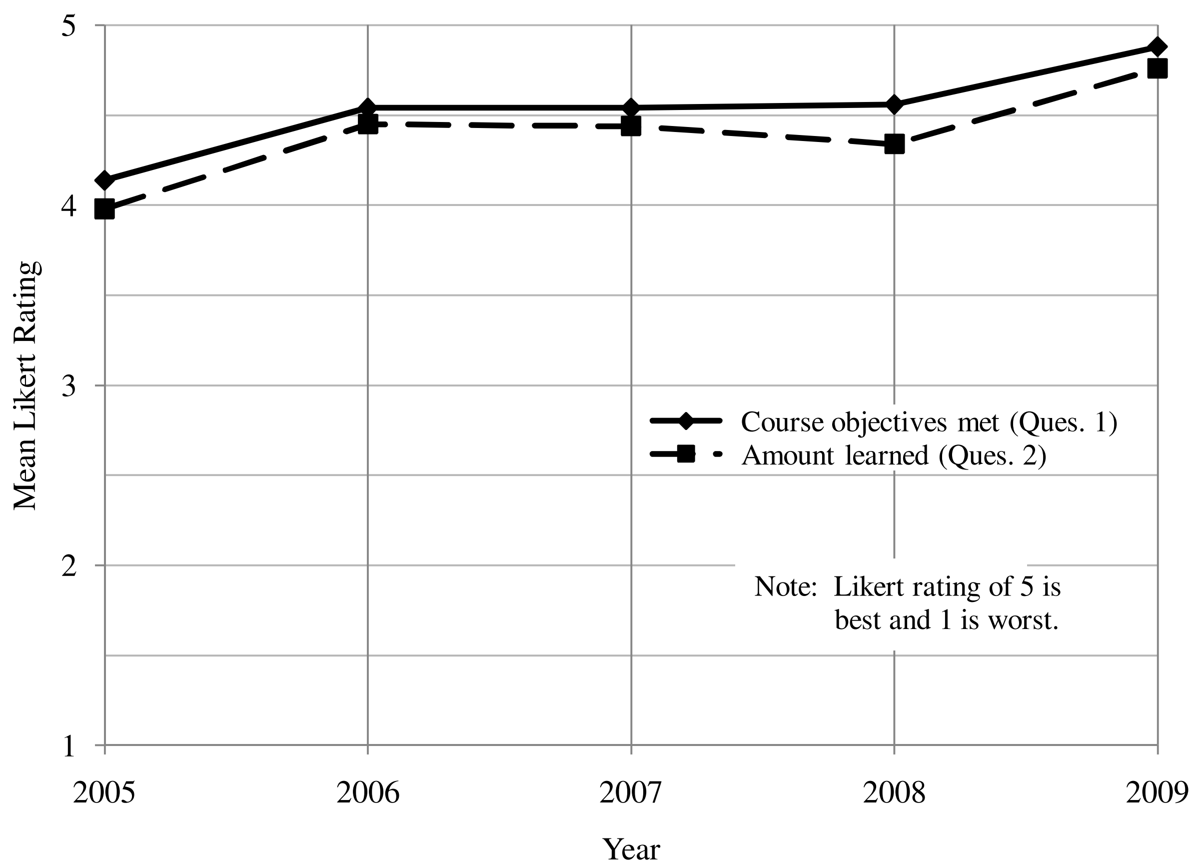

Figure 1 – Student Rating of Course

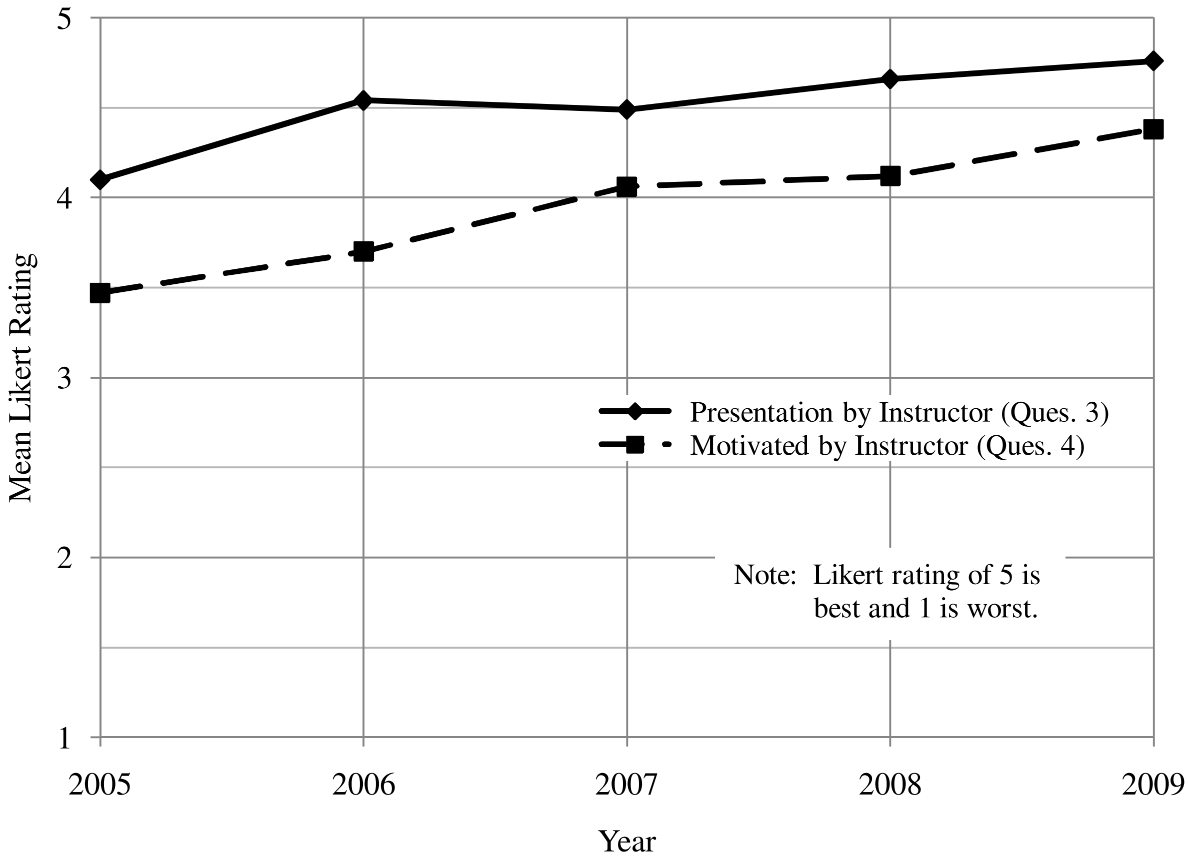

Figure 2 – Student Rating of Instructor

out of the total students enrolled in the author's course sections, were 37 of 44, 31 of 33, 39 of 45, 27 of 30, and 17 of 19 for the years 2005 to 2009, respectively. As seen from these figures, the ratings for the areas addressed by these questions had leveled off by 2008 (early increases in these ratings can be attributed to the Instructor tweaking the course in his first few years at RIT), or earlier, with the exception of the instructor's presentation of material (question 3) and the overall rating of the instructor (question 6). However, between 2008 and 2009 there are increases in the ratings for the course objectives being met (question 1 rating goes from 4.56 to 4.88), student feelings about the amount they learned (question 2 rating goes from 4.34 to 4.76), being motivated by the instructor to learn (question 4 rating goes from 4.12 to 4.38), and the overall course rating (question 5 rating goes from 4.19 to 4.59). The only significant change in the instructor's approach to teaching the course between 2008 and 2009 was the addition of the five soil behavior demonstrations to lectures in 2009. Hence it can be inferred that the use of the experiments was a potential cause for the improvement in student ratings of the course in these four areas. In addition, the improved rating for the Instructor's presentation of material (question 3 rating goes from 4.66 to 4.76) between 2008 and 2009 could also be due, in part, to the demonstrations. These types of improvements in course ratings are consistent with those seen by other authors who introduced physical demonstrations into their courses, such as Klosky and Vanderschaaf[4].

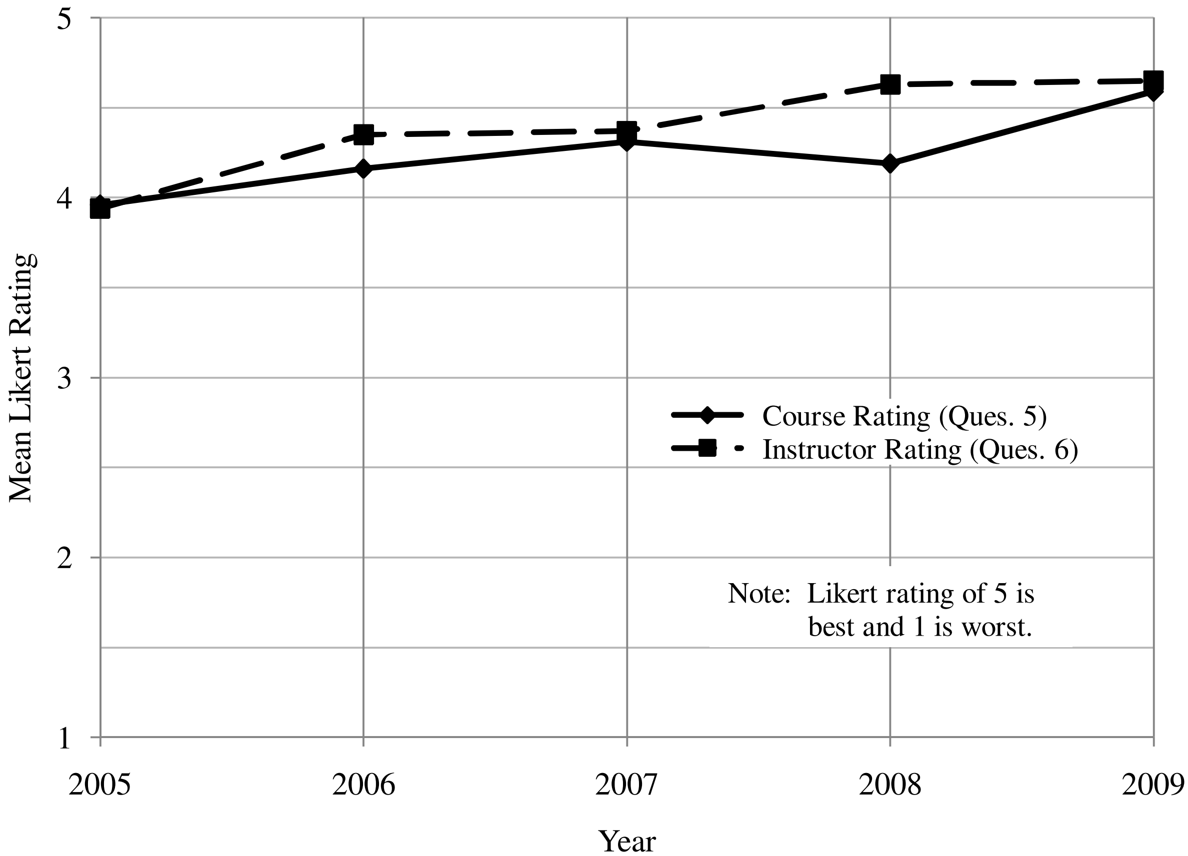

Figure 3 – Overall Student Rating of Course and Instructor

The "Student Evaluation of Instruction" form gives students the option to provide written comments regarding a course. In response to the question "What areas of this Instructor's teaching performance do you like best?", nine of the 17 students who filled out the evaluation form for the Elementary Soil Mechanics course taught by the author in 2009 indicated they liked the soil behavior demonstrations. Two of these students noted that the demonstrations helped them understand concepts and one student recommended that the number of experiments used in class be increased.

The improvements in student ratings for the Elementary Soil Mechanics course from 2008 to 2009, as well as the written comments on the 2009 evaluation forms, seem to indicate an improvement in student perceptions of, and perhaps an increased student interest in, the course. These changes in perception and interest can likely be attributed in large part to the use of the soil behavior demonstrations.

Student Performance

To investigate the potential effect of the soil behavior demonstrations on broad-based student learning in the Elementary Soil Mechanics course, a comparison was made of student performance in the author's course sections from 2005 to 2009 using the mean grades for

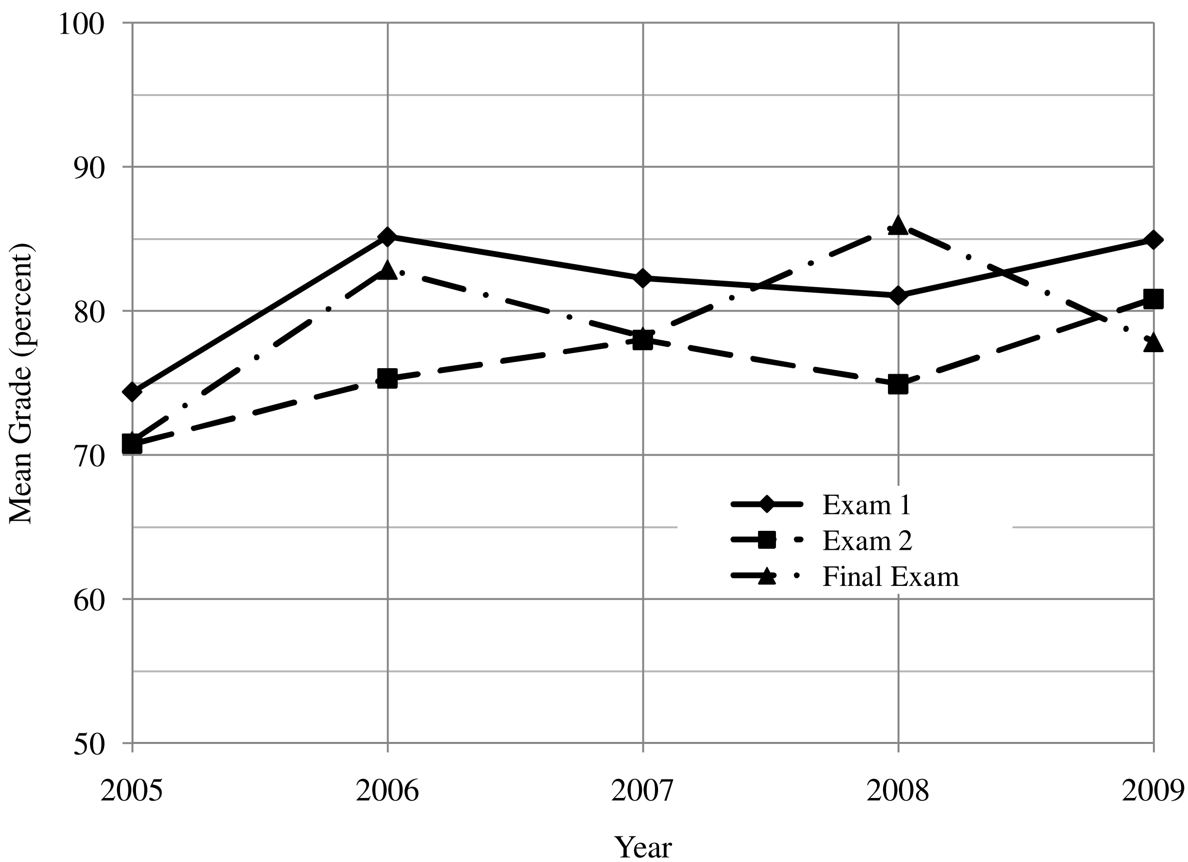

Figure 4 – Student Performance on Examinations

examinations, homework, laboratory work, and the overall course for each year, as shown in Figures 4 and 5. Since none of the coursework completed by students from 2005 to 2009 was based solely on the soil behavior concepts in the five experiments used in 2009, the comparison could provide some insight into changes in the learning of basic soil mechanics concepts and skills (other than those directly related to the five soil behaviors) and the potential impact of the demonstrations on that learning.

Figure 4 shows the variation of the mean class score on the two 50-minute-long examinations (Exams 1 and 2) and one two-hour-long final exam given in the course. Although the questions on a given exam, such as Exam 1, were not identical from year to year (in part because exams were returned to and kept by students), the exam covered the same topics each year. As seen from this figure, the mean class scores on Exams 1 and 2 had mostly leveled off by 2008. However, between 2008 and 2009 there was an increase in the mean class scores on these exams from 81.1 percent to 85.0 percent on Exam 1and from 74.9 percent to 80.8 percent on Exam 2. A two-tailed t-test performed between the mean exam scores for 2008 and 2009 indicate the difference (probability of 95 percent used) between the mean scores of the experimental group (2009) and the control group (2008) is not significant for both Exam 1 and Exam 2 (t-value of 1.12 was obtained for Exam 1 and a value of 1.41 obtained for Exam 2). However, if a probability of 90 percent is used the difference between the mean scores of the experimental and

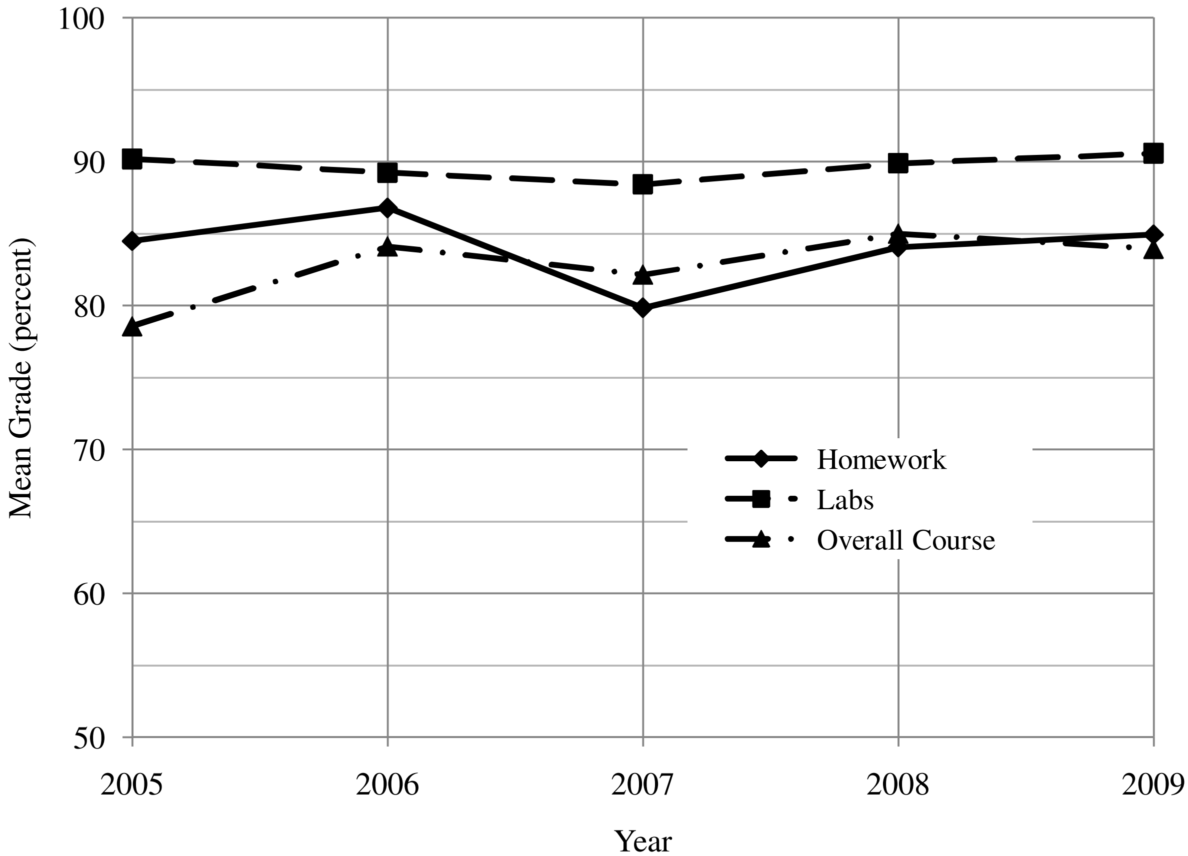

Figure 5 – Student Performance on/in Homework, Labs, and Overall Course

control groups is significant for Exam 2. The only change in the instructor's approach to teaching the course between 2008 and 2009 was the addition of the five soil behavior demonstrations.

Unlike Exams 1 and 2, the results for the final exam fluctuate over the 2005 to 2009 period and there is an actual decrease in the mean class score on the final exam between 2008 and 2009. However, this decrease can likely be attributed to a specific groundwater flow question that was only present on the 2009 final exam and caused some confusion, resulting in lower scores.

Based on the exam score data collected to date, a direct link cannot be established between the use of soil behavior demonstrations in lectures and improved student performance on exams. The inability to establish this firm connection is due to some variability in the trend of the examination scores, as well as other factors that could have contributed to the performance differences between the experimental and control groups. However, it is possible that use of the demonstrations could have partially contributed to improved student learning and performance on the two 50-minute exams, perhaps as a result of increased student interest and motivation in the soil mechanics course. A more extensive and controlled study of examination performance over time is needed to establish a strong link between the use of demonstrations and improved exam performance.

Data from the first 50-minute examination of the experimental group did provide information on the usefulness of the soil experiments for promoting student understanding of specific soil behavior. On the first exam students were asked to explain why clay has a tendency to absorb water and swell when exposed to water. Sixteen of the nineteen students in the class, which is 84 percent of the cohort, got this question 100 percent correct. Although the excellent performance of the class on this exam question cannot be completely attributed to the use of the demonstrations, the swelling of clay and clay with saltwater experiments certainly reinforced the concepts of electrically-charged clay particles and their interaction with water. Therefore, those two demonstrations likely contributed to the high success rate on the exam question.

A question was placed on the 2009 final examination to check student recognition of conditions producing earthquake-induced liquefaction of loose, saturated sand, along with the potential impact of this phenomenon on a supported structure. This question was used to evaluate the effectiveness of the liquefaction demonstration performed in class. Eleven of the 19 students who took the final exam, or approximately 58 percent of the class, correctly indicated that the conditions given could cause liquefaction effects. The lower performance on this question could be attributed, in part, to the experiment and discussion being squeezed into the last day of class, as well as the increased complexity of the soil behavior. However, there was still overall recognition of the liquefaction phenomenon by students.

Figure 5 shows the variation of the mean class grade for homework, laboratory work, and the overall course over the period 2005 to 2009. For the most part, the mean class scores for these components of coursework have leveled off by 2008 at about 85 percent for homework, 90 percent for laboratory work, and 85 percent for the overall course. As seen from Figure 5, there is not a substantial change in student performance for these coursework components between 2008 and 2009. Thus, the use of the soil behavior demonstrations did not appear to have a substantial impact on these components.

The trends seen in student performance using mean grades for different classwork components were also observed when using the median grades. Although the use of the soil behavior demonstrations, along with the potential increased student interest and motivation in the soil mechanics course that likely resulted, did not produce improvements in all areas of student performance, it could have caused some of the observed improvement in examination performance. The potential impact of demonstrations on improved student learning in a course, particularly for concepts not directly tied to the demonstrations themselves, requires further investigation.

Conclusions

From the information collected in this study, it can be concluded that the use of simple soil behavior demonstrations in the lecture of an undergraduate soil mechanics course is an effective means for increasing student thinking and understanding of key soil behaviors. Such an approach also appears to improve students' perceptions of, and interest in, the soil mechanics course. As a result, the broad-based learning and performance of the students in the course could potentially be improved, even beyond the concepts tied directly to the demonstrations, but more conclusive evidence of this effect is needed.

When implementing these demonstrations into a soil mechanics course, it is important to do so in a fashion that promotes student involvement in the experiments. This involvement can be increased by first providing the students with some background concepts related to the soil behavior that a demonstration will highlight and then allowing them to predict, in advance, what will happen. Once an experiment is completed, students should then be given an opportunity to explain what occurred based on the concepts that they have learned. In addition, students should participate in carrying out the experiment, whenever possible, to increase their feeling of involvement. Humor, when appropriate, is an additional effective tool for getting the attention of students. This overall approach increases student engagement in the activity and should promote greater learning.

This study shows there is an overwhelming positive response from undergraduate students when soil behavior demonstrations are properly used in an introductory soil mechanics course to illustrate concepts being learned in lecture. Such demonstrations are an extremely effective means for increasing student engagement in the classroom, thereby promoting greater understanding and learning. This approach should continue to be promoted, developed, and researched in civil engineering and general engineering curriculums.

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