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Integrating Research to the Undergraduate Geotechnical Engineering Classroom

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Abstract

An investigation was conducted to actively incorporate research activities into an introductory geotechnical engineering laboratory course. Students developed research programs of varying levels of sophistication as part of the laboratory course. Hands-on testing was emphasized and students were required to develop their own testing programs for demonstration of soil mechanics principles. Field experiments were encouraged and undertaken by some of the students. Laboratory experimental investigations and summaries of geotechnical construction methods were also undertaken by some of the students. The presentations of the research activities, test programs, and experimental results were completed in various formats including oral presentations to the class, poster presentations, and production of films. Separate activities have been conducted to incorporate research presentations by undergraduate and graduate research assistants to a geotechnical engineering laboratory course and included tours of advanced laboratories and field test sites as part of the course. These combined learning exercises are part of a broad investigation related to incorporation of unconventional learning styles to a geotechnical engineering laboratory course. Students have generally enjoyed the experiences and specific pedagogical benefits have been realized. An overview of the teaching methodology and assessment of student performance is described in the paper.

Introduction

A significant amount of literature is available supporting the benefits of having undergraduate students involved in research activities. Many of the previous experiences with undergraduates conducting research relate to highly structures programs, such as Research Experience for Undergraduates (REU) Programs sponsored by the National Science Foundation (e.g., Refs. 1, 2)

Other similar devoted research efforts for groups of undergraduate students have been reported with funding from other sources, including an industry-sponsored program (e.g., Ref. 3) and a state-agency sponsored program (e.g., Ref. 4). These activities with devoted research programs are generally large in scope.

Bringing research to the classroom also has been reported for K-12 classrooms (e.g., Refs. 5, 6). In addition, Research Experience for Teachers (RET) Programs (also sponsored by the National Science Foundation) have been widely reported (e.g., Refs. 7, 8).

Several of the studies have involved bringing research activities directly into the curriculum (e.g., Refs. 9, 10, 11, 12). Most of these investigations appear to keep research as the focal point of the experience for the students. Sanford-Bernhardt and Roth reported multiple options for administratively promoting research activities for students.[9] Others have reported research-oriented capstone project experiences (e.g., Ref. 10). A lesser amount of research experiences for conventional lecture and/or laboratory courses has been reported (e.g., Refs. 11, 12), especially in civil engineering. When incorporated, students have reacted favorably to having curricular content that is not present in textbooks.[11]

The current investigation has aimed to integrate some aspects of research into a geotechnical engineering laboratory course with limited impact on the existing content of the course (i.e., maintaining emphasis on conventional geotechnical engineering testing). This experience is not intended to be production-level research, but instead an introduction to research methodology and perspective for undergraduate students. Various teaching methodologies have been incorporated to the introductory geotechnical engineering laboratory at California Polytechnic State University, a primarily undergraduate institution. The laboratory is a junior level course and is a required course for all civil engineering students at California Polytechnic State University. These activities have been undertaken over the past 4 years. An overview of the teaching methodologies, assessment of the activities, and recommendations for implementation are presented.

Description of Teaching Methodologies

The teaching methodologies employed to integrate research into the course are presented in Table 1. Details of each of the methodologies are presented in the table.

Table 1. Teaching Methodologies

Methodology	Details
Introducing variables to conventional laboratory test methods	Using materials selection and scale of experimental testing device to provide comparisons of test results that are meaningful for sustainable engineering design. Beneficial reuse of wastes for geotechnical engineering applications has been emphasized.
Class field trip to local landfill	Highlight ongoing field research and the geotechnical significance of waste containment facilities.
Develop experimental methods to determine engineering properties of soils	Completely open-ended process wherein students have access to all materials and equipment in the laboratory to develop a technique for determination of specific gravity of soil solids.
Guest presentations to classroom by undergraduate and graduate research assistants	Share experiences and findings related to geotechnical engineering research both to broaden the scope and content of the course and provide a perspective of working in a research capacity.
Requiring students to analyze geotechnical engineering case histories	Demonstrate importance of standardized testing to determine engineering properties of soils and the implications for design and performance. Forensic analysis completed when possible.
Requiring students to develop experiments to demonstrate soil mechanics principles	Demonstrate principles of soil mechanics and geotechnical engineering, Inclusion of laboratory and field components for testing. Variable degrees of sophistication.
Presentation of results and interpretation using unconventional modes	Including poster sessions, teaching modules (i.e., students serving as teachers), production of films, graphics-only documentation. Emphasizing unconventional learning styles.

During one term, students were required to determine geotechnical properties of recycled materials (e.g., shredded rubber tires, plastic chips, crushed glass, aluminum shavings). This exercise provided a theme of sustainable construction while allowing flexibility in how the experimental testing would be conducted. The class was divided into 4 groups (approximately 4 students in each) and each group selected a material to investigate experimentally. The group then decided what engineering property they would analyze and developed an experimental testing program. Aside from material selection, limited variables were introduced to the testing programs. These experiments represented conventional soils tests conducted on new materials. In some cases, large-scale testing was conducted to account for larger particles associated with the recycled materials.

During a second term, the class toured the local landfill and associated large-scale research testing facility (Figure 1). The scale of testing (large-scale and field-scale) was related to their normal testing devices in the geotechnical engineering laboratory. The site that was visited has an active research program, so students could observe firsthand the scale and scope of research activities.

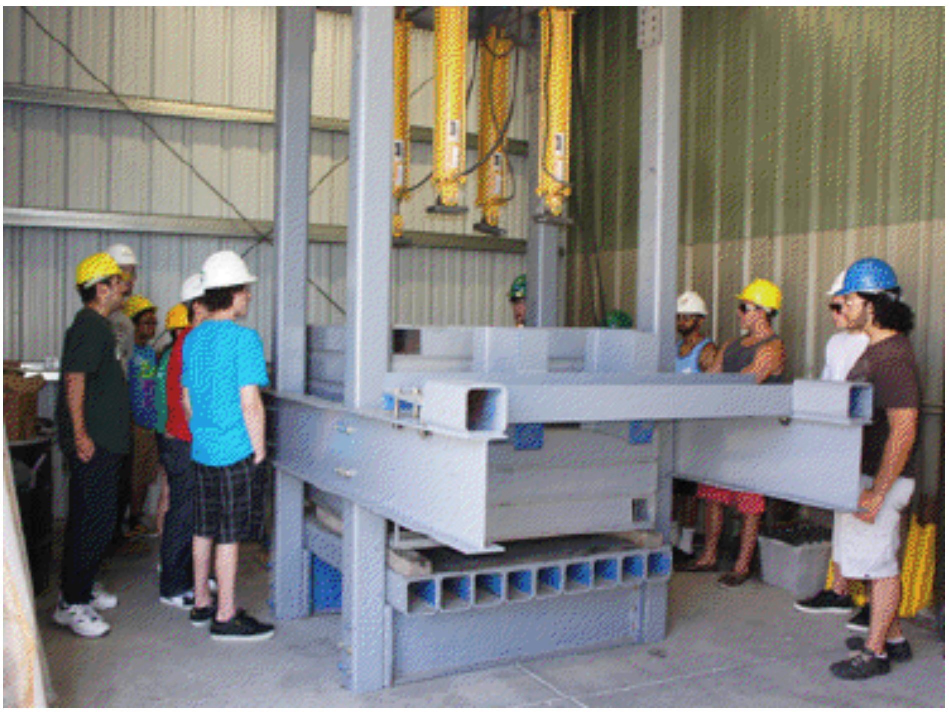

Figure 1. Photograph of class tour to local landfill and large-scale geomechanical testing facility for wastes

During a third term, the students were required to develop their own experimental methods to determine the specific gravity of soil solids. This is a fundamental concept in geotechnical engineering, yet requires detailed testing procedures. For this activity, the students were interviewed (and filmed) after the exercise as they provided a brief summary of their methodology to determine specific gravity of soil solids. The standardized testing method was shared with the students (by demonstration) only after they had completed testing using their own techniques.

During a fourth term, current research assistants made guest presentations to the geotechnical engineering laboratory course. This activity served to broaden the course content with description of timely advances in geotechnical and geoenvironmental engineering as well as providing a face for geotechnical engineering research. The presentations were generally short (5-10 minutes) and provided details regarding experimental and numerical work. In some cases, research equipment was demonstrated to the class.

During numerous previous terms, students were required to investigate geotechnical engineering case histories and identify key attributes to project success or failure as they related to soil mechanics. For the case history research projects, students selected a given project and described the geotechnical background associated with the design and/or failure. Various levels of technical sources (e.g., textbooks, archival journal articles, websites, personal communication with practitioner) were required to be included for the literature review aspect of the projects.

During numerous previous terms, students became engaged in discovery-based learning through open-ended experimentation to demonstrate principles of soil mechanics and geotechnical engineering. The oral presentations were given live in class and videotaped for review. For the experimental demonstrations of soil mechanics principles, students used experiments published as *Soils Magic* as guidelines for their activities.[13] Students selected an experiment/demonstration, conducted and videotaped the experiments, described the equipment needed for the demonstration, described the relevant theory behind the soil behavior, and related the experiment to a real-world geotechnical application. This represents a scaled-down (and student-produced) version of the full *Soils Magic*[13] show that was broadcast to the students via video conference by the Soils Magician, Dr. David Elton (Auburn University). For the open-ended experimentation, students were provided sufficient time for thorough planning and were provided a small budget for supplies and materials to support their investigations. The students reacted favorably to this format and took this assignment seriously. This assignment became the cornerstone of the class for the terms that this activity was included and effectively replaced a final examination. For several times this activity has been incorporated, we held a planning session for an entire laboratory period two to three weeks before the project was due. This timeline allowed sufficient time for development of scope, purchasing of materials, conducting experiments, and analyzing and interpreting results.

Throughout this investigation, alternative modes of presenting analysis, results, and interpretation were required. The emphasis of this aspect of the investigation was to incorporate unconventional learning styles. The formats required used included poster sessions, teaching modules (i.e., students serving as teachers), production of films, and graphics-only or audio-only documentation. These methods are described in further detail elsewhere.[14]

Student Performance

Students became engaged in discovery-based learning through open-ended experimentation to demonstrate principles of soil mechanics and geotechnical engineering. When required to integrate new materials (recycled products) into conventional geotechnical engineering testing, the students quickly made appropriate connections between soil mechanics theory and these new particulate-based media. Students were required to broaden their definition of geomaterials in considering particle packing arrangements, interaction of particles, and transport of fluids through particulate media.

The field trip to the local landfill was a beneficial addition to the course to permit the application of geotechnical testing to geoenvironmental engineering problems. Observing different scales of testing while on the field trip permitted the students to gain appreciation for fundamental concept of underlying experimental methods and the need to scale apparatus to an appropriate size to provide representative testing conditions for larger particle geomaterials.

For development of testing methods for specific gravity, most student groups developed methodology similar to the standardized method (based on volumetric displacement of soil particles in water). The path to arrive at the team-defined procedures was much more rigorous in conceptual development than simply following a published standardized method. The post-exercise summary interviews were highly effective at efficiently documenting cognitive achievements of students. Results of the standardized method were compared to the results from the methods developed by the students. This provided opportunity to discuss important mechanisms, testing details (e.g., deairing using vacuum), and sources of error in testing.

For the guest presentations by research assistants, students were engaged with the presenters and asked questions about technical content as well as research work environment. This activity had benefit for both the students and the presenters. Inclusion of new research topics and works-in-progress permitted exciting discussions about geotechnical engineering. The presenters enjoyed the opportunity to share their work to a class and the students were comfortable with the research assistants to enter into meaningful discussions.

When students developed their own problem statements and conducted small-scale research projects (or investigation of geotechnical engineering case histories) to report to the class, the benefits of inquiry-based learning were highlighted. The students generally took this assignment seriously and developed test programs that would serve as a strong basis for Masters Thesis. The projects were not as formal or extensive as graduate level research, however the students gained an appreciation for design of experiments. Several of the groups conducted extensive field experiments including field demonstration of wave erosion protection using geotextiles (pullout tests conducted at a local beach) and investigation of water infiltration rates to different surficial soil types around San Luis Obispo County. More often than not, the scope of the experimental test program had to be edited (based on recommendations from the instructor) from original student-developed plans as to not require excessive workload for the course. This demonstrates the students' enthusiasm for this new course content.

For presentation of results in unconventional modes, use of videotaping as well as graphics-only and audio-only presentations have proven to be effective at engaging students and providing pedagogical benefits. Specifically, these alternative modes make students think differently about their documentation of the research and learning process. Accountability of teamwork has improved with use of video technology in a laboratory classroom. Having students serve as teachers and conducting poster sessions have both served to increase student interactions within a classroom setting. These different course settings also provide opportunity for entertaining interactions (e.g., "Oscar Awards" for best films presented in class).

Assessment of Methodology

Assessment of project activities has been conducted using a) peer evaluation of student work, b) the Felder-Silverman Learning Style Dimensions, c) student surveys, d) focus group video conferences between students and two external assessment consultants, and e) analysis of student work products.

A rubric was developed for peer review, ranking oral presentations and videos when presented to the class. The peer review process required students to actively participate in the presentations as their review comments were considered part of their course grade. Students were generally constructive with comments to their classmates for improving public speaking skills.

From Felder-Silverman Learning Style Dimensions evaluations, overall students were relatively balanced on the sequential/global scale, showed a moderate preference for sensing and active learning styles and had a strong preference for visual learning.

Student surveys were conducted early in the project schedule, however focus groups with external reviewers were selected as a preferred method for collecting assessment data. The focus groups conducted in a private room with no instructors present, either in person or via interactive video, depending on term. This format, in itself, represents an innovative project development that has proven effective for acquiring assessment data from students. Students participated in assessment focus groups in small teams of 3-4 students.

Students reported finding value in creating video and other alternative lab reports. Specifically, students reported that they changed their approach to the laboratory reporting, preparing more carefully when they have to teach the concepts involved, working more as a team, and paying closer attention to detail when performing the laboratory experiments. For some assignments, students raised concerns regarding time required for production of films. In general, these concerns have reduced as student population has become more accustomed to working with digital videos in their personal lives.

Overall, observing students in this capacity has provided an opportunity to identify promising research assistants. The instructors took note of well designed and presented experimental testing programs and approached these students for employment opportunities after the course was completed.

Recommendations for Implementation

Recommendations for successful implementation of these teaching methodologies are presented below. Sufficient time for planning needs to be available. A devoted planning session (i.e., entire laboratory period) for the establishing the experimental programs is essential. Mentoring can take place with each group in identifying appropriate variables for inclusion in the test program and scale of testing can be designed to be at a reasonable, yet meaningful level. The entire class implementation of experimental investigation (i.e., determination of engineering properties of recycled materials) was considerably streamlined from a course administration standpoint as compared to open-ended geotechnical experiments. This method is recommended for smaller scale pedagogical interventions. Proper planning for alternative modes of presentation can provide the greatest benefits and reduce student frustration with new technologies. Filming and video editing on smart phones has simplified the process of incorporating video to the classroom setting.

Summary and Conclusions

An investigation was conducted to integrate research activities into a geotechnical engineering laboratory course at California Polytechnic State University. Various methodologies were used for including inquiry-based learning to the curriculum. Alternative modes of presenting analysis and results were required that incorporated numerous unconventional learning styles. From this investigation the following conclusions were drawn:

1) Incorporation of research directly to the undergraduate curriculum engaged students and elevated and expanded the scope of course content.
2) Approaching research as a single class activity (e.g., investigation of beneficial reuse of recycled materials in geotechnical applications) was administratively more streamlined than having student groups conduct individual research projects.
3) Inclusion of a field trip to a research site was a valuable laboratory session to highlight large-scale and field-scale research activities.
4) Having research assistants provide summaries to a classroom benefits both the course (in terms of expanding content) as well as the researchers (providing a presentation/teaching opportunity).
5) Devoting class time for proper planning of student-developed test programs is necessary to assure that the scope remains manageable, yet meaningful.
6) Observation of students completing these assignments provided an opportunity to identify promising research assistants.
7) Incorporation of alternative learning styles for presentation of experimental results and interpretation has proven to be engaging and pedagogically sound.

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