Successful Laboratory and Field Experiences with Undergraduates and K-12 Students: A Geotechnical Engineering Example

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1. INTRODUCTION

In the field of geotechnical engineering, principles of mechanics are used to analyze and predict the behavior of earth materials (i.e. soil and rock). Expertise in this area, which is usually gained through a degree in civil engineering, is required for the design and construction of most, if not all, civil structures. Bridge piers, building foundations, embankments, retaining walls, dams, and roadways are all examples of civil engineering works that require geotechnical engineering analysis, to some degree.

Being able to analyze and predict the behavior of soil and rock can, at times, be a very a difficult task for a geotechnical engineer. Difficulties arise when dealing with deposits of soil and rock because they are hidden from view, their thickness and location can vary tremendously, and their engineering behavior can be very complex and highly variable. Often, geotechnical engineers are required to base their designs on a very limited amount of information which is gathered from only a small number of drill holes and a few laboratory tests on relatively small specimens. These limitations require that geotechnical engineers acquire extensive, varied practical experience, exercise good judgment, and learn the value as well as the limitations of all related laboratory and field experiments.

A primary goal of the geotechnical engineering program at California Polytechnic State University, San Luis Obispo (Cal Poly) is to train aspiring geotechnical engineers in common laboratory and field testing procedures so that they gain practical experience and learn the importance of good judgment. The faculty believe that this teaching approach prepares the students for the rigors of the geotechnical engineering industry. Employers agree, given the fact that most students "hit the ground running" after graduation and are able to immediately make valuable contributions to practice.

At Cal Poly, students interested in geotechnical engineering find a curriculum that is almost entirely laboratory- and field-focused. Students learn using a truly "hands-on" approach. Admittedly, the development of the geotechnical program has taken a significant amount of time and effort; it did not come easily. Described in this paper is the process that the author has followed in developing what is believed to be a successful lab- and field-based engineering program for undergraduates. Also included is a discussion of recent experience that the author has had in developing similar, though "toned-down", engineering exercises and demonstrations for K-12 students. It is hoped that the information, or tips, presented will be valuable to educators working in engineering disciplines that require lab and/or field experience.

2. THE GEOTECHNICAL ENGINEERING PROGRAM

2.1 Background

The Civil and Environmental Engineering (CEEN) Department at Cal Poly is housed within the College of Engineering. The Department provides approximately 750 undergraduates with a theoretically sound, practice-oriented education. Taught by 18 tenured and tenure-track faculty and several local professionals, the program consists of 207 quarter units with courses in each of the five traditional civil engineering sub-disciplines: environmental, geotechnical, structural, transportation, and water resources engineering.

Undergraduate CEEN students are required to take one course and one laboratory in basic geotechnical analysis. A student interested in geotechnical engineering may then choose from eight geotechnical engineering electives offered by the CEEN Department. Field investigation practices, shallow and deep foundation design, slope stability analysis, geotechnical earthquake engineering, and earth pressure theory are among the topics covered in the elective courses. High undergraduate student enrollments are typical in all of the geotechnical engineering courses offered. Enrollment statistics taken over a ten year period indicate that an average of 300 seats are filled in geotechnical analysis and design courses each year.

The geotechnical engineering program within the CEEN Department is directed by two full-time faculty and by one part-time lecturer who practices geotechnical engineering in the San Luis Obispo area. Each of the geotechnical courses are well supported by members of the professional community who serve as guest lecturers and participate in the development and evaluation of student design projects.

2.2 Undergraduate Instruction

The faculty of the geotechnical engineering program believe that laboratory-based instruction is essential for aspiring civil and environmental engineers. Therefore, five of the ten geotechnical engineering courses offered by the CEEN Department have been developed specifically with a laboratory component. Laboratory sessions are commonly held in the field, in one of two well-equipped teaching labs, or in one of two computer-aided design studios. During a typical ten-week quarter, a laboratory course will have six to eight organized lab sessions, each lasting anywhere from three to six hours. The lab sessions, designed with help from industry, simulate situations that students will eventually see in professional practice. Required laboratory reports and term projects are modeled after project reports provided by outside geotechnical engineering consultants.

The field-based geotechnical engineering courses offered at Cal Poly are somewhat unique due to the fact that the CEEN Department owns geotechnical field testing equipment not commonly found at other universities. Since 1986 the Department has owned a trailer-mounted cone penetrometer testing system. The system is outfitted with two cones, a flat-plate dilatometer, and an electronic data acquisition system. Recently, the data acquisition system was upgraded using funds provided by a National Science Foundation (NSF) Division of Undergraduate Education Instrumentation and Laboratory Improvement Award (DUE #9751318).

In addition to the cone penetrometer system, the CEEN Department owns a truck-mounted drill rig, which was purchased, in part, with funds provided by the NSF grant described above. The drill rig, a Mobile B-53 Explorer, is outfitted with hollow-stem augers, mud-rotary testing equipment, and various soil samplers.

Over the past year, the author has taught two geotechnical engineering courses based almost entirely in the field: CE 482 - Conventional Subsurface Exploration and CE 582 - Advanced Geotechnical Testing. Each class had an enrollment of 14 students. In the CE 482 course, student teams used the drill rig to complete a geotechnical subsurface investigation for a site on the Cal Poly campus. The results of field and laboratory tests completed throughout the quarter were then incorporated into a comprehensive geotechnical investigation report. In the CE 582 course, student teams used the cone penetrometer system to investigate a site on campus. Data gathered in the CE 582 course were then used to design a simple building foundation.

Student evaluations indicate that the field courses are very well received. Overall instructor performance ratings for the CE 482 and CE 582 courses were 4.0/4.0 and 3.9/4.0, respectively. Example student comments taken from the evaluation surveys are included below.

"Probably the best class I have taken at Cal Poly, very hands-on, very educational, very relaxed atmosphere, etc. I feel I have gained a skill with definite value in the work force."

"I learned a lot in this class."

"This was the most interesting and exciting class I have ever taken."

"Nice to learn about field methods that we are not exposed to in the classroom."

"Great course, should be offered in the future."

"This was a very interesting class as well as informative. I learned quite a bit about the workings of a drilling rig and how soil samples are collected."

3. PROGRAM DEVELOPMENT

At this time, laboratory- and field-based exercises have been successfully established in the basic geotechnical engineering "service" courses as well as within individual courses like CE 482 and CE 582. But, how did the program arrive at this point? The evolution of a laboratory- and field-focused geotechnical engineering program at Cal Poly required extensive research, careful planning, and hard work. In general, five steps were taken during the development of the geotechnical engineering program: (1) Research the profession, (2) Develop a curriculum, (3) Generate support, (4) Acquire equipment and supplies, and (5) Teach and evaluate.

3.1. Research the Profession

Focused research is required prior to the development, modification, or refinement of a program curriculum. This research helps in establishing program goals and objectives which, in turn, help to define the topics that should be focused on in the different courses of the curriculum. Some course topics are defined based on personal experience. However, some course topics must be defined based on information gained from outside sources. Outside research should be focused toward those individuals or organizations who will be the consumers of your product. In other words, where do you want, and expect, your graduates to be successful? For an institution like Cal Poly, the primary consumers are members of industry. However, this may differ for other institutions. For example, a mission of a university may be to train students to eventually be successful in graduate school and/or research institutions.

During the development of the geotechnical program, the author drew upon his own experiences working in practice as a consulting engineer. These experiences helped to define essential qualities for graduates which, in turn, helped to define essential curriculum topics. To gather more curriculum-related information, the author informally interviewed numerous industry professionals. Previous colleagues, friends from school, local engineers, and industrial advisory board members were all found to be extremely valuable sources of information. In addition, the author referenced conference and trade publications for curriculum-related information. These publications commonly include articles that focus on topics important to the profession.

At Cal Poly, the survival of the engineering program requires participation from members of industry; there has to be a demand for graduates. A side benefit of the industry cooperation that exists is the support that is developed for the program. This support can come in many forms (see Section 3.3). It must be emphasized, however, that the author does not advocate the development of an engineering program based entirely on outside influences. There has to be a balance. Some personal bias is necessary to ensure that the curriculum caters to the instructors' strengths. Building upon an instructor's strengths stimulates personal interest in the subject and helps the program to grow. An investigation into other university engineering programs can provide valuable information when attempting to achieve a balance of personal versus outside involvement in curriculum development.

3.2. Develop a Curriculum

Within this paper, a curriculum defines the courses to be taught and their sequencing. In general, a program curriculum should be developed and/or modified only after the teaching goals and objectives for the program are established.

At Cal Poly, a principal objective of the geotechnical engineering program is to allow students as much time as possible working with important laboratory and field testing equipment. Thus, the program faculty, in developing the geotechnical curriculum, have attempted to ensure that no geotechnical engineering course is entirely classroom-based. Some courses have been designed to have a very significant laboratory component. For example, the two field-based courses described previously (CE 482 and CE 582) incorporate two hours of lecture and six hours of field work, each week. Another course, CE 581, has a similar format, but the six hours of lab are spent in the laboratory.

Those courses that incorporate the traditional classroom approach to instruction are, by design, not completely devoid of laboratory instruction. In these courses, no formal laboratory component exists. However, students are introduced to lab and field tests related to the subject through demonstrations carried-out with available testing equipment. The goal is to expose the students to as much "hands-on" experience as possible.

Overall, the field of geotechnical engineering is rather broad. Therefore, in most program curricula, several important geotechnical topics are usually grouped together and taught in a single course. In this curricular format, only a limited amount of time is spent on certain topics, even though some of these topics are considered very important to the profession. Other engineering programs undoubtedly follow this approach to course and curriculum development, given instructor time constraints, available resources, and student interest. A possible justification for this approach: The course serves simply as an introduction to the topics covered. Over time, in industry or in graduate school, the students will eventually receive the experience needed to master these topics.

At Cal Poly, the opposite approach has been taken toward course development. Here, courses more often focus on a single topic. For example, at Cal Poly the topic of slope stability is discussed in a single course lasting ten weeks. However, at other universities, this topic may be discussed over a three to four week period as part of a more general geotechnical engineering course. At Cal Poly, what are perceived to be the most important topics of the profession have been singled-out and placed into individual courses. Material presented in these courses is covered in detail at a reasonable pace. Students favor the format since they gain extensive knowledge of the subject. Members of industry appreciate the format since it reduces training time of newly hired graduates. Instructors favor the format because of the satisfaction derived from covering a subject in the necessary detail.

Finally, with regard to course sequencing, the faculty of the geotechnical engineering program at Cal Poly have had success incorporating a "gate" into the curriculum. As stated, civil and environmental engineering students are required to take one lecture course and one laboratory course in geotechnical analysis. These courses are pre-requisites to a course in shallow foundation design (CE 481), which is an elective course that serves as a gate in the geotechnical engineering curriculum. The shallow foundation design course is considered a gate since it is the pre-requisite to the remaining seven elective courses taught within the program. The gate is an excellent curriculum management tool since it controls enrollments in the more specialized geotechnical engineering courses while helping to ensure that everyone has the skills necessary to pass these courses. A secondary benefit of the gate is that students who pass through the gate to the more specialized courses are usually very interested in geotechnical engineering. As a result, they show more commitment to the elective courses and subject material being taught.

3.3. Generate Support

Once in place, a program needs to be promoted. The main goal of promotion is to help others recognize that what you are doing is successful. With program recognition will come program support. Support, which will appear in many different forms, is essential for the continued success of the program.

The promotion of an engineering program as well as its teaching goals and objectives can take several forms. At Cal Poly, a bi-annual newsletter and Web page have recently been developed. The geotechnical engineering faculty use these publications to promote student activities, special projects, and industry cooperation. The newsletter and Web page are focused primarily toward alumni and industrial representatives. Both can be tremendous sources of support. Given the importance of alumni and the key role they play in the promotion and support of a program, it is essential that they be tracked following graduation. At Cal Poly, a geotechnical engineering alumni database was recently developed by the faculty. Such a database is recommended for all engineering programs.

In addition to publishing the newsletter and Web page, the faculty of the geotechnical engineering program regularly submit program-related articles and photographs for publication in College and University newsletters and annual reports. Often, the University and local newspapers are also contacted if community service related activities are to be promoted. Finally, some other less obvious forms of program promotion include: faculty-student collaboration on papers and reports, faculty nominations for geotechnical-related student awards and scholarships, active development of service projects for the local community, and educational outreach to local K-12 schools. All of these activities help to positively promote the program to some degree, which leads to increased support.

Program support is the main goal of program promotion. This support, which can come in many different forms, is essential if an engineering program is to continue to grow and to be successful. In its simplest form, successful promotion will help in the recruitment of students to the program. This issue is becoming extremely important in civil engineering given the fact that enrollments are declining. Promotion can also lead to institutional support from the Department, College, or University. Successful programs are much easier to support than unsuccessful ones. In a similar sense, promotion can be very important in the generation of external funds from alumni and industrial professionals. At Cal Poly, emphasis is placed on laboratory- and field-based instruction. A program with such an emphasis can become expensive. Thus, a promotion plan was developed with the specific goal of raising the funds necessary to run the program.

Finally, besides money, program support can come in other forms. Some examples include: field trip ideas, guest speakers for courses, class design projects, senior project ideas, service project ideas, and equipment donations. All of these benefits have been recognized at Cal Poly, even though the faculty have spent only a relatively small amount of time developing a promotion plan.

3.4 Acquire Equipment and Supplies

Most laboratory courses are expensive to teach. It is acknowledged that this high cost may even help to discourage the development or continuation of laboratory-based programs at some universities. At Cal Poly, the cost of running the field laboratory courses is especially high, given the maintenance and upkeep required for the heavy equipment utilized. Given this high cost, the faculty have worked hard to develop the support structure necessary to fund such an operation. Certainly, other engineering programs do not require the operating budget necessary for a hands-on geotechnical engineering program. However, it is believed that the comments in this section should be valuable to all engineering programs, regardless of their size or focus.

Of course, grants are one source of income for laboratory- or field-based instructional programs. Equipment grants related to both research and education are available through the National Science Foundation, the Department of Defense, and various foundations and institutions. A discussion of these funding sources and their available funding programs is beyond the scope of this paper. A great deal of information is available through the Web or through a university grants development office. It should be emphasized, however, that these agencies fund capital improvement projects. Rarely can funds be solicited specifically for supplies or operating expenses.

Funds for supplies and operating expenses can be allocated through a home department, college, or university. Aggressive promotion of your program can translate into funding from these organizations. However, given the constraints on university budgets, funding from these organizations cannot be expected to be very high.

To help alleviate any financial burden for the CEEN Department at Cal Poly, the author voluntarily implemented a yearly fundraising program. The author's fundraising program targets alumni and private firms practicing geotechnical engineering. Initially, relationships with potential donors were established over about a 12 month period. Each potential donor was contacted by phone and sent a detailed "prospectus" describing the geotechnical engineering program and its goals. After initial contact, funds were solicited from the donors with a specific objective: to help purchase the drill rig. The response to this solicitation was overwhelming. During an eight month period, approximately $8,000 in funding was raised which allowed the project to proceed toward completion. In the end, the funds raised were used as matching on the NSF award described earlier.

Since the initial fundraising campaign, the author has attempted, with some success, to establish a steady stream of donated funds to the program. Currently, about $2000 is being raised on a yearly basis. The goal is to eventually raise $10,000 each year in support of the geotechnical laboratories. At this time, new fundraising plans are being considered and evaluated with the hope of implementing a strategy by later this year. In the meantime, program awareness is being improved with a promotional campaign that involves a newly developed Web page and a bi-annual newsletter.

3.5. Teaching and Evaluation

Of course, with the curriculum, support, and equipment in place, the final step is to fulfill the goals and objectives of the engineering program. The goals and objectives are accomplished through teaching. At Cal Poly, the geotechnical engineering faculty have approximately two years of experience teaching a laboratory- and field-focused curriculum. There have been successes and failures. Student evaluations and self-assessment by each faculty member have led to program improvements and refinements. This process is continuing. Within the following section of this paper are some tips/tricks that the geotechnical engineering faculty have found valuable in teaching lab- and field-based courses.

4. TIPS FOR UNDERGRADUATE INSTRUCTION

While teaching field- and laboratory-based geotechnical engineering courses over the past several years, the author has implemented several new programs and experimented with different teaching techniques. Listed below are some general tips that, in the author's opinion, should help lead to successful field and laboratory experiences for undergraduate engineering students.

4.1 Practical Exercises

Keep the exercises practical. At the undergraduate level, students are starved for information related to field which they are about to enter. Practical field and laboratory exercises help to tie-together what they have learned over the past four to five years. At Cal Poly, the "start-to-finish" approach taken in the field-based courses appears to be very attractive to the students. In these classes, students are involved in every aspect of a geotechnical investigation. Typically, they will plan the investigation, establish a budget, perform the investigation, reduce and interpret the data, and use the data in analysis and/or design. Realistic project "themes" developed with help from industry are commonly used.

4.2 Student Responsibility

Trust the students. For the author, one of the most frightening aspects of a laboratory course is allowing a student to operate a very expensive piece of equipment. However, a student is much more interested and will likely learn more when allowed to perform the work "hands-on." At Cal Poly, student response for the CE 482 course has been extremely positive. In the course, drilling and sampling with the CEEN Department drill rig is carried-out by the students with minimal instructor supervision. Before relinquishing control, it is recommended, however, that the instructor spend at least one laboratory session training the students on proper use and maintenance of the equipment. In addition, students will always have more appreciation for a piece of equipment if its value to the department and cost are clearly defined.

4.3 Safety

With increased student responsibility comes the increased need for safety. Work in the field and in the lab can, at times, be dangerous if the students become too relaxed or bored. At Cal Poly, safety training is included in the first laboratory session when the equipment is introduced. In addition, safety manuals have been prepared for the labs and for the individual field testing systems. Students are required to read the manuals and complete a "safety quiz" prior to working with any laboratory equipment. The safety training helps to limit accidents and to ensure that the students will conduct themselves in a professional manner.

4.4 Advanced Preparation

Be prepared. Unfortunately, it has been the experience of the author that a well organized, interesting laboratory, in some cases, will take nearly as long to prepare as it does to complete. However, this preparation is essential. A well organized and well prepared laboratory will demand the students' attention and will allow the instructor to make the most of the time available. Overall, good preparation conveys professionalism and commitment.

Of course, student teaching assistants can be valuable in preparing for labs. At Cal Poly, undergraduate students assistants are often employed or given course credit to help prepare laboratories and equipment for instruction. The return on such an investment is usually very good since the assistants are eager to earn some money and learn at the same time. The students generally take pride in being able to help the department in some way; they feel like they are part of the team. In the past, the author has had great success recruiting student assistants from the departmental student organizations. Usually, these organizations keep a member database. A "special skills" entry in the database can be used to help find students with, for example, welding, carpentry, or construction type skills, which may be important when assisting in the laboratory.

4.5 Industrial Contacts

It can be advantageous for a new faculty member to establish contacts with engineers practicing in the local community. Local contacts can provide example design projects, ideas for field and laboratory exercises, ideas for field trips, and example engineering reports. In addition, such contacts are normally more than willing to serve as guest speakers. Upon joining the faculty at Cal Poly, the author immediately established contact with several local geotechnical engineering firms. The university-industry cooperation that has occurred since has made the geotechnical courses very rewarding for students. The cooperation enables the instructor to easily relate many "real life" examples during the presentation of a course. In addition, the cooperation allows for classroom illustration of different perspectives on analysis and design.

4.6 Faculty Involvement

Finally, a laboratory- and field-based instructional program requires commitment by full-time faculty. As demonstrated, the lab and field activities associated with geotechnical engineering are just as important as the concepts presented in the classroom. Why leave this lab and field instruction in the hands of a student Teaching Assistant? At Cal Poly, TA's are rarely used in lab or field instruction. Often, the faculty work in the lab and in the field with the students. This time commitment by the full-time faculty helps demonstrate to the students the importance of the topics and lessons being learned.

5. DEVELOPMENT OF A K-12 INSTRUCTIONAL PROGRAM

Recently, the faculty of the geotechnical engineering program, with help from Cal Poly senior project students, have begun to organize geotechnical engineering exercises and demonstrations for K-12 students in the San Luis Obispo area. The feeling is that hands-on experience in an outdoor environment, with dirt, heavy equipment, and computerized data acquisition systems, will help to stimulate interest and excitement in science, mathematics, and engineering. A recent drop in undergraduate student enrollment within the field of civil engineering has hinted that the promotion of engineering at the K-12 level may be necessary. However, regardless of whether or not the recent enrollment trends are a true concern or just an anomaly, working with the K-12 age students is extremely enjoyable and very rewarding.

At this time, a demonstration for 4th through 6th graders has been developed, tested, and evaluated. A high school demonstration is currently being prepared, though it has not yet been tested. Subsequent comments pertain to work that has been completed with the 4th through 6th graders.

A typical elementary school class demonstration involves hands-on experimentation with soils and rocks. Initially, a mobile geotechnical engineering laboratory is brought to the elementary school classroom along with a team of undergraduate instructors. The 1½ hour long demonstration that then takes place is broken into four parts. First, through an informal discussion, the elementary school students are introduced to terms important in civil engineering and geotechnical engineering. Then, while still in the classroom, the students are divided into groups of 6 to 10 students each and are asked to perform several basic geotechnical engineering experiments. Through these experiments, the students 'play with dirt' while learning about important soil properties such as permeability, grain size, plasticity, and water content. In addition, they learn how to classify gravelly, sandy, and clayey soils. All of the experiments are very hands-on and are closely monitored by undergraduate instructors.

After the experiments are completed, the elementary school students are shown a brief slide show on geotechnical engineering. Included in the slide show is a discussion of how a drill rig is used to retrieve soil samples from beneath the ground for laboratory testing. Eventually, the students are led outside where they receive a hard hat and safety instructions. Then, they get a real-life view of Cal Poly's drill rig. The students watch as the drill rig is used to excavate a relatively shallow borehole. Then, a soil sample is retrieved using a simple soil sampling device. The students are asked to classify the retrieved soil sample based on the concepts that they have previously learned in the classroom.

To date, elementary school demonstrations have been completed for three 4th through 6th grade classes in the San Luis Obispo area. Based on evaluations taken after the demonstrations, the K-12 students and teachers have been very receptive The plan is to perfect the K-12 demonstrations over the next several months so that the demonstrations can eventually be performed on a regular basis.

6. TIPS FOR K-12 INSTRUCTION

Over the past several months, the author, along with his undergraduate instructors, have gained a tremendous amount of experience in dealing with elementary school students. Listed below are some general tips that, in the author's opinion, should help lead to successful laboratory and field experiences for K-12 students. These tips are based directly on the results of recently completed K-12 demonstrations. Following these demonstrations, comments (i.e. evaluations) were solicited from the undergraduate student instructors, the K-12 students, and the K-12 instructors.

6.1 Develop a Formal Lesson Plan

Prior to entering an elementary school classroom, a formal lesson plan was developed around a specific set of learning objectives. These learning objectives were formulated in meetings between the author and several undergraduate student instructors.

The lesson plans were then refined based on conversations with local K-12 instructors as well as the results of practice sessions performed for undergraduates posing as K-12 students. This careful, up-front planning has been successful, given the fact that the demonstrations have worked very well without modification for three different schools.

Overall, the primary objective of the K-12 lesson plan was to introduce students to the fields of civil engineering and geotechnical engineering. A secondary objective was to teach these students about soil and rock classification and its importance in geotechnical engineering. A tertiary objective of the lesson plan, which was added after consultation with K-12 instructors, was to allow the K-12 students to practice basic math, vocabulary, and writing skills. These skills were worked into the demonstration in a variety of different ways.

Mathematics. The goal here was to illustrate the practical application of mathematics. Students were given worksheets and were asked to determine parameters important in geotechnical engineering. Soil water content was an example. The calculation of water content required simple addition, subtraction, multiplication, and division skills.

Vocabulary. One goal of the K-12 presentations was to help the students expand their vocabulary. The K-12 students were presented a list of vocabulary words associated with geotechnical engineering and geology. The spelling of these words and their definitions were then stressed throughout the classroom and field demonstrations.

Writing Skills. The K-12 students were asked to work on their writing skills. In the field, the students were given a blank field investigation worksheet. Then, they were asked to examine the soil sample retrieved during drilling. On the worksheet, the students were then required to provide a sketch of the soil sample as well as a brief, detailed description. Included in the descriptions were vocabulary words and concepts learned earlier in the classroom.

6.2 Evaluate Your Work

In K-12 instruction, as in undergraduate instruction, it is important that your teaching be evaluated. Evaluation helps in the refinement of the presented material so that the students are guaranteed a valuable and rewarding demonstration. Upon completion of the geotechnical engineering demonstrations, the K-12 students, the K-12 instructors, and the undergraduate student instructors were each asked to fill-out evaluation surveys. The instructor surveys were detailed and included questions that focused on subject matter, teaching approach, and organization. Responses to these surveys were, in general, very informative.

The K-12 student surveys were greatly simplified compared to those presented to the instructors. The students were asked to rate, on a scale of 'bad' to 'great', different aspects of the demonstration. In addition, the students were asked to note two new things that were learned as a result of the demonstration. It is interesting to note that these surveys did not provide much valuable information. For the most part, everything was 'great', and the written comments generally showed that the students were "put on the spot."

From this experience, it was learned that thank you letters provide much more valuable evaluation information. Several days after one K-12 demonstration, the K-12 instructor asked her students to prepare thank you letters for the undergraduate student instructors. These letters were very detailed and provided a great deal of insight into what worked during the demonstration and what did not. For future demonstrations, the plan is to continue to distribute K-12 student evaluation forms. However, K-12 instructors will be encouraged to have the students write thank you letters, given the previous success. Certainly, longer comment forms could be completed by the K-12 students after the demonstrations. However, it has been found that time is very limited given the fact that the demonstrations are 1½ hours long.

6.3 Recruit a Diverse Group of Instructors

It is important that the undergraduate student instructors relate to as many of the K-12 students as possible during a demonstration. Undoubtedly, your audience at the K-12 level will represent a diverse group of students. Therefore, its is recommended that the make-up of the instructors be as diverse as the audience being addressed.

As an example, in the San Luis Obispo area, many of the classes are split between white male, female, and Hispanic males/females. In an attempt to "touch" all the members of the audience, female and Hispanic instructors were added to the team. This approach appeared to be very successful. In one class of 4th graders, an Hispanic instructor was able to speak Spanish with some K-12 students who had not yet mastered the English language. In another demonstration with 6th graders, a question and answer (Q/A) session on college life was carried-out after the geotechnical engineering demonstrations had been completed. The Q/A session was led by a female instructor. Believe it or not, many of the female K-12 students were very surprised that women were encouraged to study engineering! Needless to say, the Cal Poly instructor informed the students that women do indeed have a place in engineering.

6.4 Understand Your Audience

It is important that you research what can be expected when entering the K-12 classroom. You must understand your audience. For the author, it was difficult to remember life as a 10-year old! Therefore, numerous questions were posed: What is the attention span of a student in elementary school? What math and science concepts are appropriate for K-12 students? What is the best way to deal with behavioral problems? Should the class and field demonstrations be completed in groups or with the entire class?

Fortunately, our colleagues in secondary education have already answered most of the questions listed above. Initially, the above questions were answered by researching the appropriate educational literature. Further information was then gathered by interviewing faculty members of the Education Department on campus. Finally, a tremendous wealth of information was realized after meeting, in person, with the K-12 instructors. The valuable insight provided by these instructors is absolutely necessary for a successful K-12 presentation.

6.5 Practice, Practice, Practice

The title of this section speaks for itself. When entering an unknown environment, like a K-12 classroom, you should be as prepared as possible. Prior to conducting the K-12 demonstrations, the Cal Poly undergraduate student instructors practiced in front of other undergraduates posing as K-12 students. In addition, prior to traveling to the K-12 schools, all undergraduate student instructors were given detailed written instructions and trained in the various demonstrations.

7. SUMMARY AND CONCLUSIONS

Provided in this paper was a description of the geotechnical engineering program that is taught through the Civil and Environmental Engineering Department at Cal Poly, San Luis Obispo. Over the past two to three years, the faculty of the geotechnical engineering program have worked to develop a laboratory- and field-focused curriculum. To date, numerous detailed exercises and demonstrations involving available lab and field equipment have been developed for undergraduate students as well as K-12 students. These exercises and demonstrations have been successfully tested in university and K-12 environments.

The bulk of the paper described tips/tricks for educators interested in developing or refining similar laboratory- and field-based programs. Tips regarding program development were presented. Also presented were tips for instructing undergraduates and K-12 students in lab and field environments. The tips should be valuable for engineering educators working in programs that could potentially be laboratory- and field-based (e.g. environmental, agricultural, etc.). It is believed, however, that many of the comments included in the paper were general enough that they should have some value to engineering educators in almost any discipline who are interested in lab instruction.

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